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THE

AMERICAN JOURNAL OF SCIENCE.

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MONTANA.

Several shipments of interesting minerals from Montana have lately been received, a number of the most notable being reviewed below. The great mineral wealth of this district is well-known, and to its present activity is due the increasing number of mineral species reported.

CRYSTALLIZED RHODOCHROSITE. Characteristic rhombohedrons of a rich pink in aggregates, clean cut and perfect. They lack the translucency of the Colorado find, but in other features closely resemble the material from that state. Crystals vary in size from ¼ to an inch and more across with corresponding thickness. Occasionally, groups are coated with a white drusy quartz making an association both interesting and attractive. Prices 50c. to $2.00. Massive 50c. per lb.

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Two shipments of this odd occurrence permit us to describe its varied habits and strange associations. In appearance the crystals are black, due to the fine network of included Tourmaline hairs, which occasionally are widely separated, reminding one of the more common "flêches d'amour." A peculiar "stem" extends beyond the base of some crystals, around which the Quartz seems to have formed. The Tourmaline is often isolated on the "stem," appearing in bristling tufts and masses. The very fact that these specimens differ widely from the usual Quartz forms, makes them attractive to the collector, but aside from this point they combine such interesting features scientifically, that a steady demand is anticipated. Prices 50c. to $3.50 in 2 and 4 inch sizes.

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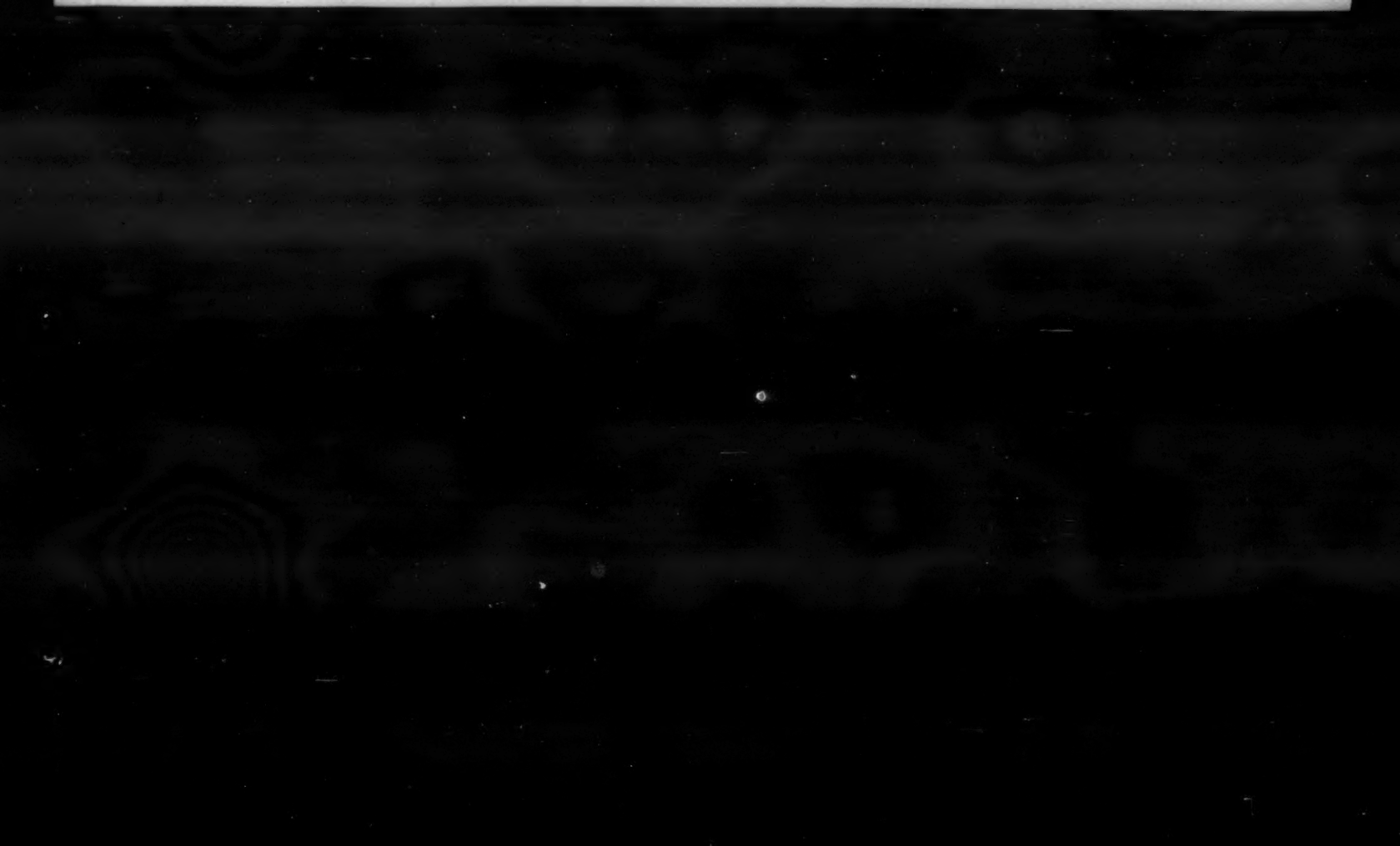


THE

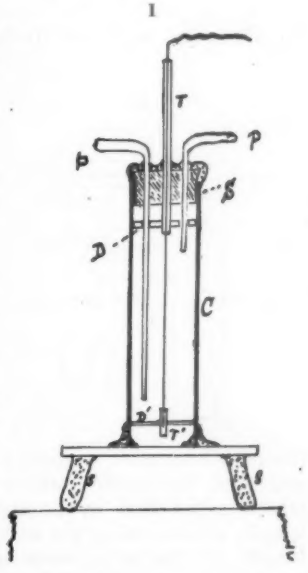
AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XVIII.—*The Discharge-current from a Surface of large Curvature;* by JOHN E. ALMY, Ph.D., Instructor in Physics, University of Nebraska, Lincoln.

1. THE discharge of electricity from a surface of large curvature has been studied by Warburg,* and others.† Inasmuch as the nature and form of the discharging surface, when a point, or pointed wire, is used, is necessarily more or less problematic, it seemed of interest to study the discharge from a fine wire of uniform dimension.

The discharge from a platinum wire of very small size to a concentric, circular cylinder has been the subject of study.



2. The discharge apparatus is shown in fig. 1. The brass cylinder, C, cemented to the glass plate, is further insulated by the supports of sealing-wax, *s*, *s*. The discharge wire, passing through the capillary tube, T, embedded in paraffin, hangs vertically, stretched by the weight of a short piece of tube, T′, in which its lower end is embedded. Paraffin discs, D, D′, serve to keep the wire at the center of the cylinder. The gas is removed and supplied by tubes P and

* Warburg, Wied. Ann., lxvii, p. 82; Ann. d. Phys. (4), ii, p. 295.
† Sieveking, Ann. d. Physik. (4), i, p. 299, etc.

p. The cork, S, which closed the upper end of the cylinder, was coated with sealing-wax, surface-leakage, even when the glass tube became coated with moisture, being thus prevented.

The electric connections are sketched in fig. 2. W, a Wimshurst machine, was driven by a small motor. A galvanometer (D'Arsonval), G, measured the discharge current; potential differences between wire and cylinder were read on a 'Braun,'—later a Kelvin, 'vertical,' voltmeter, V. Potential differences were regulated by a fine discharge-point shunting the poles of the Wimshurst.

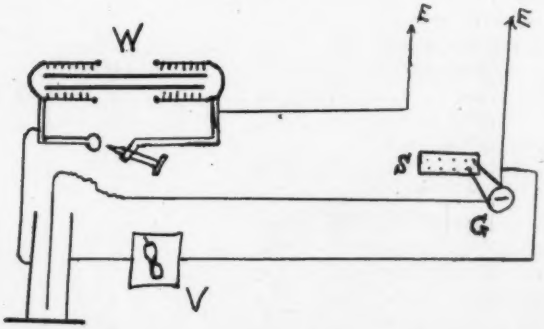
As air, which was the gas used throughout the first portion of the observations, shows some deterioration with use, when the discharge current attains to a measurable value (by "deterioration" is meant a decrease of its capacity to carry on the discharge), fresh, dried, gas was continuously drawn through the discharge apparatus.

As only relativity was wished for, the voltmeter and galvanometer were not standardized; nor were the variations of atmospheric pressure, from day to day, noted.

Observations.

3. First, the proportionality of total discharge to length of the discharge wire was tested. It was found, that so long as

2



the length of wire is greater than the diameter of the cylinder, and with the paraffin discs restricting the volume of the gas which takes part in the discharge to the solid cylinder of the length of the wire, the current is directly proportional to the length of the wire, with a given applied potential, and the minimum potential difference that will produce measurable discharge current is independent of the length of the wire.

In case short lengths (as compared to cylinder diameter)

were used, or the discs were dispensed with, exact proportionality no longer holds.

A series of observations illustrating this proportionality are given:

TABLE I.

Potentials.	Values of the quotient. L = 31cm.	L = 25cm.	Current. L = 15cm.	Wire length. L = 10cm
14	16·7	15·7	17·3	16·0
16	36·1	35·4	36·6	34·
18	60·6	59·3	60·6	60·
20	90·0	90·2	92·6	88·
22	120·	118·2	122·	120·
24	----	160·	162·	163·
26	----	----	214·	216·

Diameter of cylinder, 9·4cm. Diameter of wire, 0·0047cm.

4. The relation holding between the applied potential and the resulting discharge current is found to be expressed by the quadratic:

$$I = a L V(V-b)$$

I, V, and L, having the usual significance, and a and b are constants, depending upon the cylinder, wire, and gas. The constant b is found to approximate, more or less closely, to the "minimum-potential" of Röntgen, i. e., the least potential which will give the measureable discharge.

This law was found applicable for cylinders of diameters, from 2 to 10cm, giving agreement within errors of observation, except for potentials which differed only very slightly from the "minimum potential." Even after the gas had been used for a considerable time without renewal and also at widely varying pressures (from 20 to 80cm of mercury) the relation between current and potential remains similar, with, naturally, different constants. As illustration I cite a series, taken at random from the considerable number of observations made:

TABLE II.

V (arbitrary units.)	I (calc.)	I (observ.)	V (of cylinder.)	I (calc.)	I (obs.)
13	13·7	17·0	—14	15·3	17·
14	26·5	27·	—16	36·2	36·
16	56·	55·	—18	62·	61·
18	92·	92·	—20	92·	92·
20	135·	138·	—22	126·	122·
22	184·	186·	—24	166·	162·
24	240·	240·	—26	210·	206·
26	313·	320·	—28	260·	257·
$a = ·543$; $b = 11·7$.			—30	313·	315·
			$a = ·389$; $b = 12·15$.		

Length of wire, 15^{cm}; diameter, $0{\cdot}0047^{cm}$; diameter of cylinder, $9{\cdot}4^{cm}$; pressure of the gas (air), $74{\cdot}7^{cm}$ of Hg. The variation of the constants, a, and b, when the sign of the discharge is reversed, is, in the case of air, not large; but in case hydrogen is used a very large difference exists.

The equation given above seems applicable to the discharge under all the various conditions of the gas. Even after the gas had suffered any amount of "deterioration," so that the discharge that passed was decidedly less, the relation between potential and current still exists,—with different values for the constants, a and b.

5. The applicability of this relation at widely different gas pressures (varying from 20^{cm} to 80^{cm} of Hg.) was also established. The variation of the discharge current, with gas pressure, for a given apparatus, does not seem capable of any simple formulation. It seems probable that this was due to a difference in the rate and extent of the deterioration of the gas at the different pressures, so that the constants obtained represent different conditions of the gas, beside differences of pressure. The constants obtained are:

Pressure.	a.	b.
$20{\cdot}^{cm}$ of Hg.	3·55	3·20
40· " "	1·05	8·53
75· " "	·55—·65	11·7—12·2

The dimensions of the apparatus were those given in the preceding section.

6. For determination of the law of the variation of current with the radius of the cylinder, three cylinders of suitably different radii, with discharge wires of the same size and length, were mounted as the one used heretofore. Hydrogen, generated from hydrochloric acid with zinc, purified and dried by the usual process, was passed into the cylinders in place of air, as this gas shows less rapid deterioration with continued use. Still, under the most favorable conditions that could be obtained, the current given by a certain potential was subject to considerable variation.

It was found that to a certain degree of approximation, the total discharge current is inversely proportional to the cube of the radius of the cylinder, other dimensions being the same. It is to be noticed that this relation holds most accurately when the current in the cylinders compared is of the same order of magnitude. It seems probable that the deviation which occurs when the current in one tube is large compared to that in the other may be due to more rapid deterioration of the gas with increased discharge; in fact, the deviation is always most pronounced when the discharge is largest in both tubes.

A typical series of observations is given below: the lengths of the discharge wires were each 10^{cm}; the radii of the cylinders were $5{\cdot}0^{cm}$, $3{\cdot}2^{cm}$ and $1{\cdot}5^{cm}$ respectively; that of the discharge wire was $0{\cdot}0034^{cm}$.

TABLE III.

Applied potentials. in volts.	Current. I_1 for $r = 5{\cdot}0$.	I_2 for $r = 3{\cdot}2$.	I_3 for $r = 1{\cdot}5$.	Ratios. $\frac{I_2}{I_1}$	$\frac{I_3}{I_2}$
3500	4·0	16·0	152·	4·0	9·5
3800	----	24·	200·	----	8·3
4000	9·0	36·	290·	4·0	8·0
4500	19·	74·	480·	3·9	6·5
5000	31·	118·	----	3·8	----
5500	55·	189·	----	3·4	----
			Mean values,	3·82	8·1

The ratios r_1^3/r_2^3 and r_2^3/r_3^3 have the values 3·8 and 9·7, respectively. The variations obtained were usually within the limit of those shown in this series.

7. In résumé, then, it has been found that the current discharging from a fine wire to a concentric surrounding cylinder is given by the equation,—

$$I = \frac{L}{r^3} aV(V-b)$$

where,

I = the discharge current
V = the potential difference between wire and cylinder
L = length of the discharge wire
r = radius of the cylinder
b = the minimum potential necessary to produce a measurable discharge,
and, a = a constant depending upon the size of the wire, the discharging gas, and the sign of the discharge.

Physical Laboratory,
University of Nebraska, May, 1901.

ART. XIX. — *On Octahedrite and Brookite, from Brindletown, North Carolina;* by H. H. ROBINSON.

THE two minerals described in this article were kindly sent to Prof. S. L. Penfield by Mr. W. E. Hidden, and are from the original locality on the north slope of Pilot Mountain near Brindletown, Burke County, North Carolina, discovered by him in 1879.* They occur, according to Mr. Hidden, in detached crystals scattered through the gold-bearing gravels of the district, having been derived from the disintegration of the local schists. As accompanying minerals, are mentioned zircon, monazite, xenotime, samarskite, fergusonite, and many others.

It was thought that brief descriptions, with figures, of these two minerals would be of interest both because of their rare occurrence in the United States and because no careful investigation of the crystals from this locality seems to have been made.

1. *Octahedrite.*

The crystals studied vary in size from 2 to 5^{mm} in diameter on the horizontal axes and from 0·50 to 1·25^{mm} in thickness. The larger ones are of a deep bluish-black color and then they possess a metallic-adamantine luster, while a smaller one is quite colorless. Under the microscope, the color is seen to be due to a dark pigment which entirely pervades some crystals, while in others transparent spots are left, around the borders of which the pigment gradually fades out. A small transparent crystal, representing a section perpendicular to the vertical axis, was dark in all positions between crossed nicols. In converging polarized light, however, it was seen that the mineral was not perfectly uniaxial, as the axes of the interference figure opened slightly on revolving the section.

In habit the crystals are tabular owing to the prominent development of the basal pinacoid, *c* (001). This Mr. Hidden mentions as being the common habit. The simplest crystal examined consists of the forms *c* (001), *e* (101), *x* (103), and *p* (111), and is shown by figures 1*a* and 1*b*; of these, 1*a* is a horizontal projection (on *c*) and 1*b* shows the crystal in the usual perspective.† In figures 2*a* and 2*b* a slightly more com-

* This Journal (3), xxi, 160, 1881.

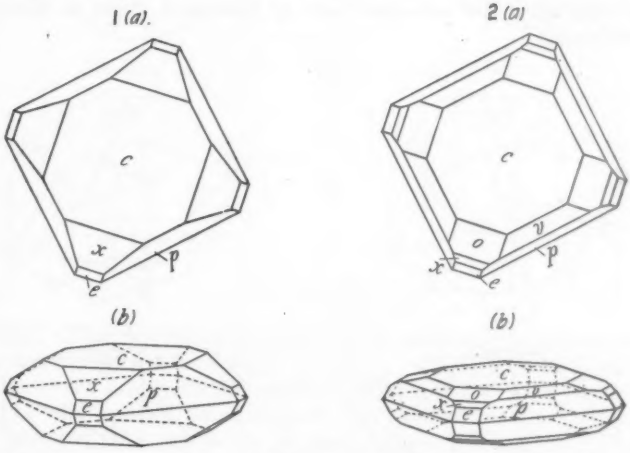
† In this article the method has been adopted of giving with each clinographic drawing of the crystals a plan, which represents a true horizontal projection of the lower figure. In most cases the drawing of such a plan greatly facilitates the construction of the customary crystal figure, giving a complete control over it, and the two figures taken together give a better idea of the crystal shape than either one alone. Since there exists the closest relationship between the two figures, it has been considered advisable to represent them in the position in which they are drawn. Accordingly each plan is shown as revolved a certain angle (18° 26′) from a horizontal position.

plex combination is represented with two additional faces, *o* (107) and *v* (117). These two figures show all the prominent forms as well as their relative development.

The complete list of faces observed is as follows:

c (001)	*o* (107)	*γ* (902)	*ν* (1·1·28)
e (101)	*d* (301)	*p* (111)	*ρ* (1·1·40)
x (103)	u_1 (5·0·19)	*v* (117)	

The errors in the measured values of the above faces as compared with the values given by Dana* range from 1′ to 10′, the average being 3½′. Though most of the faces give rather poor reflections, the measurements are all close enough to clearly establish their identity.



The form *ν* (1·1·28) was first observed by Seligmann,† who identified it with but moderate certainty, owing to the poor development of the faces on the crystals examined by him. The angles measured on two of these crystals leave no doubt as to the correctness of the indices established by him, as is shown by the following:

	Calculated.	Measured (I).	Average.	Measured (II).	Average.
$c \wedge \nu$,	5° 7¾′	5° 3′		5° 10′	5° 11′
		5 12	5° 7⅔′	5 12	
		5 8			

The above measurements and the fact that the face lies in the zone $c \wedge p$ are sufficient to establish the identity of this

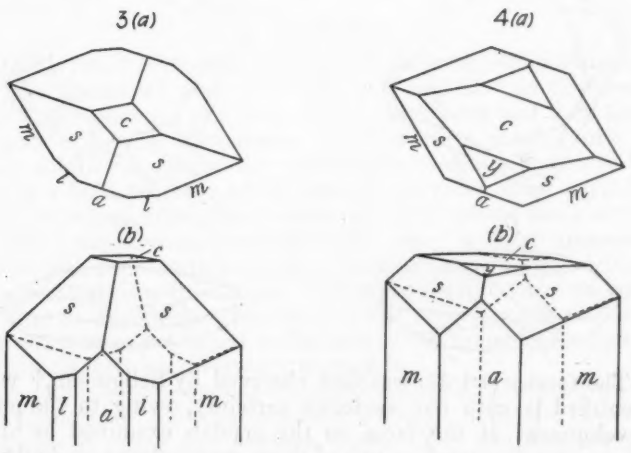
* System of Mineralogy, 6th ed., 1892, 240.
† Zs. Kr., ii, 337, 1886.

form. The faces are all of small size, yet the measurements from five give an average error of but $1\frac{1}{4}'$. On one crystal three out of the possible four forms were observed at one extremity, on a second only two.

2. *Brookite.*

Five crystals of this mineral were examined and they are of special interest because they possess a habit quite different from that ordinarily observed.

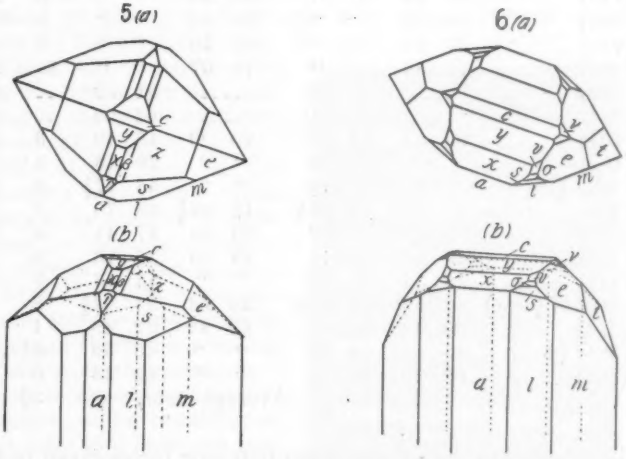
The habit of all the crystals is prismatic. Their development on the *a* and *b* axes is well shown in the plans of figures 3–6. The length in the direction of the vertical axis is from four to six times their greatest width. Being relatively so long and slender, it did not seem best to represent them as doubly terminated.



The unusual feature of these crystals is the prominent development of the pyramid *s* (322). This form was first observed by Kokscharow* as a very small face, and the only notice of its having a prominence at all like that on the crystals from this locality is in an article by Streuver, "Sulla Brookite di Buera nell'Ossola."† The habit of the crystals described by him is, however, quite different in that it is short and tabular parallel to *a* (100), the proportion between the width and thickness being as $1 : \frac{1}{8}$.

* Vh. Min. Ges., St. Petersburg, 1848–49.
† Proc. R. Acc. d. Linc. (4), vi, 77, 1890.

Figures 3*a* and 3*b* show the simplest type, the crystal being terminated by the single pyramid *s* (322) in combination with a small basal pinacoid. In figures 4*a* and 4*b*, *s* (322) is in combination with a dome *y* (104) and a much larger basal plane. Figures 5*a* and 5*b* show the pyramids *e* (122) and *z* (112), which are common on brookite, about equal in their development to



s (322). The pyramid β (5·4·10) is new, occurring, as shown, as a narrow face in a zone with *e*, *z*, and *x*. Of the domes, *y* (104) and *x* (102) are common, while τ (101) is new. In figures 6*a* and 6*b* the general habit is more like that ordinarily observed in brookite, the domes *y*, *x*, and *t*, and the pyramid *e* all being common forms. The pyramid *s* (322), σ (324), and *v* (326) are in a zone and σ (324) is new. The pyramid *v* (146) is also new. In the prismatic zone *a* (100), *m* (110), and *l* (210) are largely developed, while a (320) and *k* (410) are present as narrow faces.

All the crystals are of small size, ranging from 1·25 to 2·50^{mm} in width, 0·75 to 1·75^{mm} in thickness, and 3 to 7^{mm} in length. Their color is a dark reddish-brown and renders them too opaque for optical examination in natural sections. Vertical striations on the prismatic faces, with the exception of *m*, are always very marked, giving them a dull luster. The terminal faces are all somewhat striated, though not sufficiently to greatly injure the quality of the larger ones.

The faces observed, with their measurements as made on a two-circle goniometer and their calculated values, are given in

the following table. The scheme is that of Goldschmidt as given in his "Krystallographische Winkeltabellen."

Faces.	Measured. ϕ	Measured. ρ	Calculated. ϕ	Calculated. ρ	Error. ϕ	Error. ρ
c (001)	----	----	----	----	--	--
a (100)	89° 58′	89° 58′	90° 0′	90° 0′	2′	2′
m (110)	49 55	" "	49 55	" "	0	2
$\mathfrak{a}$ (320)	60 50	" "	60 42	" "	8	2
l (210)	67 13	" "	67 10	" "	3	2
k (410)	77 52	" "	78 07	" "	15	2
d (043)	----	51 28	----	51 32	--	4
t (021)	----	62 0	----	62 06	--	6
y (104)	89 57	15 37	90 0	15 40	3	3
x (102)	" "	29 15	" "	29 18	3	3
τ (101) (new)	" "	48 18	" "	48 17½	3	0½
ν (146) "	16 30½	33 23½	16 32½	33 18	2	5½
e (122)	30 47	47 38	30 43	47 41	4	3
z (112)	49 53	36 12	49 55	36 15	2	3
o (111)	49 54	55 47	" "	55 43	1	4
β (5·4·10) (new)	55 55	34 05½	56 03	34 04½	8	1
v (326)	60 43	32 44	60 42	32 45	1	1
σ (324) (new)	60 46½	43 49	" "	43 59	4½	10
s (322)	60 42	62 35	" "	62 36	0	1
			Average error,		3¾	3

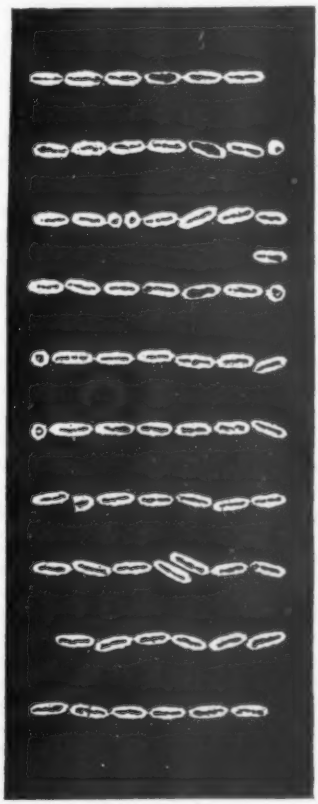
In calculating the values of the four new forms given in the foregoing table the axial ratio of $a:\breve{b}:\dot{c} = 0{\cdot}84158:1:0{\cdot}94439$, as determined by Kokscharow,* was used. The form β (5·4·10) was observed on one crystal (figure 5), three faces being present on one end and two on the opposite, out of a possible four in each case. The dome τ (101) was observed but once on the same crystal. The pyramids σ (324) and ν (146) were observed on but one crystal (figure 6), the first form being represented by two and the second by three faces.

Sheffield Laboratory of Mineralogy,
Yale University, New Haven, Conn., May, 1901.

* Mineralogie Russlands, I, 61, 1853.

ART. XX. — *On the Behavior of Small closed Cylinders in Organ-pipes;* by BERGEN DAVIS, Ph.D.

WHILE experimenting with stationary sound waves in organ-pipes, the following striking effect was obtained. A considerable number of small gelatine capsules, such as are used for medical purposes, were thrown in a promiscuous pile in the center of the pipe, and when the pipe was blown so as to give its first overtone quite strongly, the small cylinders immediately moved to the middle of the loop of the stationary wave and there arranged themselves in rows across the pipe as shown in the figure. The spacing between the rows was quite regular and the capsules acted as though there was a strong attraction at their ends, in a direction perpendicular to the vibration, and a repulsion at their sides in a direction parallel to the vibration.



An investigation was undertaken to determine the effect of the size of the cylinders, of the number of rows, and of the amplitude of vibration, upon the distances between the rows.

The stationary wave was that produced in a stopped organ-pipe speaking its first overtone. The side of the pipe was removed and a glass plate substituted for it. At the node nearest the mouth a thin rubber diaphragm was placed across the pipe, which protected the portion back of the diaphragm from disturbances arising from blowing. This region of the pipe, from the diaphragm to the stopped end, enclosed one-half of the stationary wave. The amplitude of vibration was measured by means of the force acting on a small hollow cylinder closed at

one end, as was described by the writer in this Journal.* The torsion balance carrying this cylinder was placed at the middle of the loop.

The small cylinders whose spacing in the sound wave was to be measured were of two kinds, consisting of small gelatine capsules and of paper tubes. These two kinds of cylinders were used in independent series of experiments..

Three sizes of gelatine capsules were used, commercial numbers of which are Nos. 00, 2 and 5.

The dimensions in centimeters of these cylinders are given below.

	Length.	Diameter.
No. 00	2·42	·83
No. 2	1·75	·63
No. 5	1·03	·48

A sufficient number of one of the above sizes of capsules were placed in the organ-pipe to form a considerable number of rows. In order to obtain a desirable amplitude of vibration the torsion head was turned from the zero position by an amount corresponding to a desired amplitude, then the pressure of blowing was increased until the force acting on the measuring device just balanced the torsion previously given to the wire; at the same time the capsule cylinders arranged themselves in rows across the pipe. This previous setting of the torsion head enabled me to reproduce the same amplitude of vibration at will.

In the tables below are given the average distances in centimeters between the rows for the various sizes, with increasing amplitudes of vibration. The amplitude 2A is here used to denote the total excursion of the vibrating air particles.

No. 00. *Capsule cylinders.*

Amplitudes.	Number of rows.			
2A	2	3	6	10
·39	4·	3·5	2·8	2·2
·434	3·5	3·3	2·6	2·1
·476	3·3	3·5	2·6	2·1
·548	3·5	3·7	2·7	2·2

No. 2. *Capsule cylinders.*

Amplitudes.	Number of rows.			
2A	2	3	6	10
·39	2·8	2·75	2·8	2·
·434	2·4	2·5	2·65	1·95
·476	2·5	2·5	2·55	2·
·548	2·5	2·5	2·45	2·

* This Journal, September, 1900.

No. 5. *Capsule cylinders.*

Amplitudes.	Number of rows.			
2A	2	3	6	10
·39	2·	2·75	2·4	1·9
·434	1·8	2·5	2·1	1·55
·476	2·	2·1	2·1	1·6
·548	2·	2·5	2·2	1·66

The most striking result obtained from the above tables is that the distances between rows slightly decrease with increasing amplitudes of vibration. The average distance between the rows decreases in general as the number of rows increases, excepting in the case of the smallest, No. 5 cylinders, in which case the spacing increased when three and six rows were used. This tendency to increase with these particular rows is also exhibited by the No. 2 cylinders. The general rule may also be deduced, that the larger the cylinders, the more the spacing decreases with the number of rows, as will be evident by comparing the two-row and the ten-row columns in the three tables. At the higher amplitudes the capsule cylinders were quite violently agitated, as though the position of the loop were somewhat unsteady, which increased the difficulties of accurate measurement.

The corresponding experiments were performed with paper cylinders of various diameters. These cylinders were each $6{\cdot}3^{cm}$ in length and were open at both ends, on account of the circumstance that the length of one of them was nearly equal to the diameter of the pipe. Since the effect to be observed was a result of the forces acting at the sides and not at the ends, the open ends did not affect the experiment. The open ends were of advantage in that they lessened the force with which the cylinders in all cases adhered to the walls of the pipe.

The diameters of these cylinders in centimeters are given below:

No. 1	·5
No. 2	·71
No. 3	1·00
No. 4	1·4

These paper cylinders were introduced into the closed chamber of the pipe and the same experiments performed as with the capsule cylinders. Each cylinder now corresponds to a row as described in the previous experiments. The same amplitudes of vibration were retained for the purpose of comparison. The results are given in the following tables:

No. 1. *Paper cylinders.*

Amplitudes.	Number of rows.			
2A	2	3	6	10
·39	3·2	3·2	2·6	2·1
·434	2·6	3·2	2·5	1·9
·476	2·3	3·2	2·5	1·9
·548	2·3	3·2	2·4	1·9

No. 2. *Paper cylinders.*

Amplitudes.	Number of rows.			
2A	2	3	6	10
·39	6·5	3·	2·7	2·3
·434	6·	3·	2·8	2·3
·476	6·	3·2	2·9	2·2
·548	6·	3·2	2·8	2·2

No. 3. *Paper cylinders.*

Amplitudes.	Number of rows.			
2A	2	3	6	10
·39	6·	4·3	3·9	2·
·434	5·5	4·	3·	2·
·476	5·	4·	----	----
·548	5·	4·	----	----

No. 4. *Paper cylinders.*

Amplitudes.	Number of rows.			
2A	2	3	6	10
·39	7·	5·5	3·3	2·8
·434	6·5	5·	----	----
·476	6·5	----	----	----
·548	----	----	----	----

Here again it will be noticed that the space between the cylinders slightly decreases with increasing amplitudes of vibration. The space between the rows decreases as the number of rows increase. This result is somewhat different from that obtained with the No. 2 and No. 5 capsule-cylinders, while the same result was obtained as with the large No. 00 capsule-cylinders. The blanks in the columns with the larger cylinders when several rows were used, are due to the fact that the tone passed over into the next overtone before the required amplitude was reached. This was probably due to the effect of friction. The presence of so much obstruction tended to form a node at this point, which is near the natural

position of the node of the next overtone. When this overtone occurred, the rows would divide into two portions, which moved toward the middles of the two loops of the new stationary wave.

A striking effect was obtained by placing a number of the smallest capsule-cylinders a short distance from the node. When the pipe spoke, they immediately ran rapidly to the middle of the loop, and there assumed a regular arrangement.

The effects described in this paper are of course of the same nature as the Kundt dust figures. The individual capsule-cylinders may be considered as dust particles in which the size has been much increased, the particles still remaining light enough to respond readily to the delicate forces to which they are subjected.

Prof. Rood suggested as an explanation of the spacing that a sound-shadow is formed on the two sides of the cylinders at each half vibration, alternately. These shadows, being regions of less motion, press so to speak against the cylinders. When there are two rows the shadows between the cylinders press them apart until the force just equals that pressing against the outside or nodal sides of the two cylinders. This also explains their rapid movement from the nodes toward the loop. The average velocity on the side nearest a node is less, and hence the pressure greater than on the side nearest a loop, where the velocity is greater. The behavior of the capsule-cylinders illustrates the distribution of the forces acting upon rigid bodies in moving fluids, the mathematical analysis of which has been so fully developed by W. Koenig.*

The effect here described can be easily reproduced as a lecture experiment. The ordinary stopped organ-pipe found in lecture cabinets will suffice for the purpose. The smaller capsules will perhaps be found to give the effect more strongly in case the pipe is not a powerful one.

Physical Laboratory of Columbia University, June 1, 1901.

* Wied. Ann., xlii, pp. 353, 549, 1891.

ART. XXI.—*On a Cæsium-Tellurium Fluoride;* by H. L. WELLS and J. M. WILLIS.

SEVERAL tellurium double fluorides have been described: $NaF \cdot TeF_4$ by Berzelius, $KF \cdot TeF_4$, $NH_4F \cdot TeF_4$ and $BaF_2 \cdot 2TeF_4 \cdot H_2O$ by Högbom.* It is noticeable that all these fluorides belong to a type which is different from that of the double chlorides, bromides and iodides of tellurium, e. g., $2KCl \cdot TeCl_4$, $2RbBr \cdot TeBr_4$ and $2CsI \cdot TeI_4$, etc., which have been thoroughly studied in this laboratory by Wheeler.† We have undertaken, therefore, an investigation of the combination of cæsium fluoride with tellurium fluoride, with the expectation that possibly several types of double fluorides might be obtained. After a systematic examination of the matter, however, we were able to prepare only one double fluoride, $CsF \cdot TeF_4$, which corresponds in type to the previously known fluorides.

A concentrated solution of TeF_4 was prepared by dissolving about 10^g of pure TeO_2 in an excess of strong hot hydrofluoric acid, and to this cæsium fluoride was added in small portions, the liquid being concentrated by evaporation and cooled after each addition. At the same time small portions of tellurium fluoride were added to a concentrated solution of about 50^g of cæsium fluoride in hydrofluoric acid and this solution was evaporated and cooled in the same manner. Under the widest range of conditions, however, only a single double salt was obtained.

1 : 1 Cæsium-tellurium fluoride, $CsF \cdot TeF_4$.—This salt crystallizes beautifully in large, transparent, colorless needles. The presence of free hydrofluoric acid is necessary for its formation, for it is decomposed by water. Several crops, made under widely varying conditions, were analyzed with the following results:

	Calculated for $CsTeF_5$.	Found. I.	II.	III.	IV.
Cæsium	37·36	36·59	37·50	38·56	37·23
Tellurium	35·96	35·51	36·45	35·82	35·60
Fluorine	26·68	26·76	24·51	26·18	----

Fluorine was determined volumetrically by converting it into SiF_4, collecting this in water, and titrating with a standard solution of potassium hydroxide. In another portion, after evaporating with concentrated sulphuric acid and dissolving the residue in hydrochloric acid, tellurium was precipitated with sulphur dioxide, collected on a Gooch crucible and weighed as metal. From the filtrate from the tellurium cæsium was obtained, and weighed as normal sulphate.

Sheffield Scientific School, May, 1901.

* Bulletin, xxv, 60.

† This Journal (3), xlv, 267.

Art. XXII.—*On the Double Chlorides of Cæsium and Thorium;* by H. L. Wells and J. M. Willis.

Nearly all of the known double halogen salts of quadrivalent metals belong to a single type, of which $2KCl{\cdot}PtCl_4$ and $2KF{\cdot}SiF_4$ are examples. It has been shown, however, by Marignac* and by Wells and Foote† that the double fluorides of zirconium exist in a variety of types. Therefore, since thorium is somewhat closely related to zirconium, we have undertaken an investigation of some thorium double halides, and have selected the cæsium salts as being the most promising.

Upon attempting to prepare cæsium thorium fluorides we found that thorium fluoride is practically insoluble even in concentrated solutions of cæsium fluoride containing hydrofluoric acid. There is no doubt that the two fluorides combine under these circumstances, but since we obtained only finely divided precipitates as products and there was no certainty as to their purity, further work on the fluorides was abandoned. Chydenius‡ has previously described two potassium thorium fluorides, $2KF{\cdot}ThF_4{\cdot}4H_2O$ and $KF{\cdot}ThF_4{\cdot}\frac{1}{2}H_2O$, but on account of the insolubility of thorium fluoride and of these double salts it is probable that there may be some doubt in regard to the correctness of these formulæ.

We have prepared two cæsium-thorium chlorides, to which we assign the formulæ $3CsCl{\cdot}ThCl_4{\cdot}12H_2O$ and $2CsCl{\cdot}ThCl_4{\cdot}11H_2O$. The amount of water of crystallization in these compounds is somewhat uncertain, since they form very small hygroscopic crystals, and it is difficult to dry them by pressing on paper. The search for double chlorides was made systematically by starting with a solution of about 6^{5} of thorium chloride in hydrochloric acid, adding 2 to 4^{g} of cæsium chloride at a time, and evaporating and cooling after each addition until finally, after dividing the solution and using a part of it, a very large excess of cæsium chloride was present.

In analyzing the salts, chlorine was determined as silver chloride, sometimes in separate portions, in other cases in the filtrates from which thorium hydroxide had been precipitated; thorium was weighed as oxide after precipitation with ammonia, and the cæsium in the filtrates was converted into normal sulphate and weighed as such; water was determined by difference.

* Ann. Chim. Phys. (3), lx, 257. † This Journal (4), i, 18; iii, 466.
‡ Pogg. Ann., cxix, 43.

3 : 1 Cæsium-thorium chloride, $3CsCl \cdot ThCl_4 \cdot 12H_2O$.—This salt was produced from solutions containing about 12^g of thorium chloride and from 30 to 110^g of cæsium chloride. It forms colorless crystals of feathery structure upon cooling very concentrated solutions. Three different crops made under somewhat varied conditions gave the following results upon analysis:

	Calculated for $Cs_3ThCl_7 \cdot 12H_2O$.	Found. I.	II.	III.
Cæsium	36·45	36·21	36·14	....
Thorium	21·20	20·70	21·68	21·05
Chlorine	22·61	23·09	....	23·37
Water	19·74	[20·00]	....	....

2 : 1 Cæsium-thorium chloride, $2CsCl \cdot ThCl_4 \cdot 11H_2O$.—This salt was obtained in colorless crystals, somewhat resembling the previous salt, but not nearly as feathery in appearance. It was formed in concentrated solutions containing about 65^g of thorium chloride and from 30 to 100^g of cæsium chloride. The following analyses were made of different crops:

	Calculated for $Cs_2ThCl_6 \cdot 11H_2O$.	Found I.	II.	III.	IV.
Cæsium	29·26	29·84	29·10	28·92	....
Thorium	25·52	25·42	25·41	25·70	25·22
Chlorine	23·43	23·40	24·75	23·35	23·55
Water	21·78	[21·34]	[20·74]	[22·03]	....

The salt loses water slowly in the desiccator over sulphuric acid. A sample dried in this way lost 6 per cent in two days, 11 per cent after one week, and 20 per cent, corresponding to practically all the water, after one month.

The two chlorides that we have obtained are different in type from the potassium salt $KCl \cdot 2ThCl_4 \cdot 18H_2O$ described by Cleve* and from the ammonium salt $8NH_4Cl \cdot ThCl_4 \cdot 8H_2O$ described by Chydenius.† It seems certain that the ammonium salt just mentioned represents a mixture, for it is described as a sintered mass made in the dry way.

Sheffield Scientific School, May, 1901.

* Bulletin, xxi, 118.

† Pogg. Ann., cxix, 43.

Art. XXIII.—*Studies of Eocene Mammalia in the Marsh Collection, Peabody Museum;* by J. L. Wortman.

[Continued from p. 154.]

Hind limb.—The greater part of the pelvic bones of both sides are present, from which an accurate idea of this portion of the osteology can be formed. In comparison with the ilium, the ischium, figure 32, is elongate, being 73 per cent of the length of the former bone; in *Herpestes* it is 79, in *Crossarchus* 69, in the Binturong 66, and in the domestic cat 65 per cent of the length of the ilium. The peduncular portion of the ilium exhibits about the same degree of constriction as that seen in the Binturong, and is somewhat greater than in *Herpestes*. The gluteal surface is little expanded, and is occupied by two longitudinal grooves separated by a prominent rounded ridge; of these the superior is the wider and deeper, the inferior being long and narrow. This division of the gluteal surface is a characteristic feature of the pelvis of all Eocene Carnivora, and in some species it persists into the Oligocene. In the living forms, it has very generally disappeared, only a trace of it remaining in some of the less specialized types. The meaning of its universal presence in the early types is to be accounted for on the supposition that the primitive

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Figure 31.—Phalanx of *Oödectes herpestoides* Wortman; dorsal view; two and one-fourth times natural size. (Type.)

32

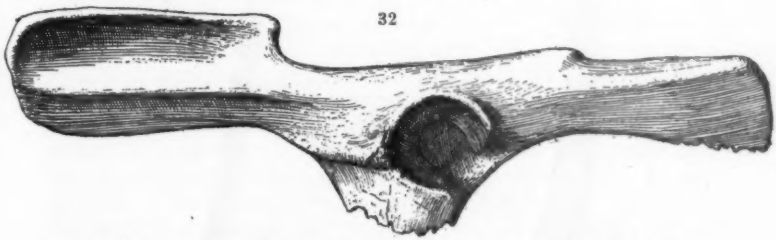

Figure 32.—Portion of left half of pelvic girdle of *Oödectes herpestoides* Wortman; side view; three halves natural size. (Type.)

Marsupial-like ancestors had a type of ilium similar to that of the living Opossum, in which it consists of a simple elongated trihedral bar attached to a single vertebra. Slight expansion of the dorsal and ventral borders of this bar would give the conditions seen in the Eocene types, wherein the longitudinal ridge corresponds to and is the remains of the primitive bar.

A little in front of, and below the acetabulum is a relatively large rugose area, which served to give origin to the *rectus femoris;* it is rather large and this part of the bone somewhat

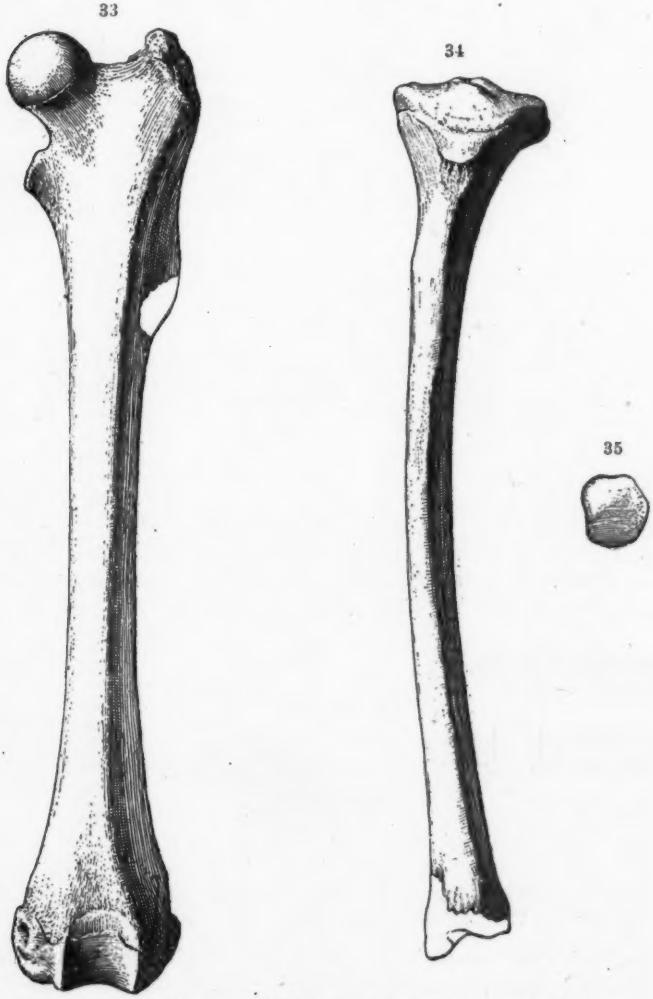

FIGURE 33.—Left femur of *Oödectes herpestoides* Wortman; front view.
FIGURE 34.—Left tibia of same species; front view.
FIGURE 35.—Left patella of same species; front view.
All figures are three halves natural size. (Type.)

deep, resembling in this respect the corresponding part of the pelvis of the Binturong. The ischial tuberosities were little developed, as in the Ichneumon, and there is but slight indication of the ischial spine.

The femur, figure 33, is relatively stout and has a straight shaft. The hemispherical head is set upon the shaft by a short, thick neck, and the *fovea capitalis* for the terete ligament is distinct. The *trochanter major* rises to the level of the head, and the digital fossa is deep, narrow, and slit-like, as if it had been compressed from before backwards, as in certain of the carnivorous Marsupials, notably the Dasyures and Opossums. The *trochanter minor* is broad and placed upon the inner side of the shaft just below the neck. The distal end of the bone is characteristic, being relatively broad and flat. The condyles are well separated and have comparatively little posterior extension; they are sub-equal in size, and the inner is not produced downwards to any perceptibly greater extent than the outer. The rotular groove is broad and shallow and has but slight upward extension upon the anterior surface of the shaft. In all its characters, with the exception of the third trochanter and the large size of the *trochanter minor*, the femur bears a very strong resemblance to that of the Binturong, and differs from the viverrine and herpestine representatives in the character of the distal end, the shape of the greater trochanter, and the position of the lesser, which is more on the inner border of the shaft. The patella, figure 35, moreover, is short, flat, thin, and scale-like, having more the shape of that of the Binturong, in marked contrast to its narrow, elongate, thickened form in the other sections of the family.

The tibia, figure 34, does not closely resemble that of any of the living Viverridæ on account of the preponderance of primitive characters which it possesses. These are seen in the relatively small size, the slender and rounded shaft, its great lateral curvature, and the small development of the cnemial crest. The head has the appearance of being flattened from before backwards; the two tuberosities have the usual form, but the spine is very much less divided than in the modern species. The entire form is quite as much like that of the Marsupials as that of the living types. Near the middle of the shaft or what may be taken as the extreme lower end of the cnemial crest is seen a prominent roughened area for tendinous attachment. This area is also pronounced in the tibia of many Marsupials; and is likewise present, but less strongly marked, in the Binturong. If it served for the attachment of the tendon of one of the inner hamstring muscles, which is in all probability the case, it indicates an unusually low position for this insertion. A short distance above, and to the inner side, is seen the point of insertion of

the remaining tendons of the inner hamstring. The distal end is unknown.

With the exception of some fragments of the middle portion of the shaft, the fibula is not preserved. These fragments indicate that it was comparatively little reduced, a character which again takes it back towards a Marsupial stage of development.

The pes is represented by but a few inconsiderable fragments, which do not, unfortunately, serve to give a very clear idea of its organization. A distal extremity of a calcaneum corresponds much more nearly with that of the Binturong than either *Herpestes*, *Crossarchus*, *Viverra*, or *Eupleres*. The articular surface for the cuboid is rather flat, the astragalar facet much arched, and the sustentaculum widely projecting, with a slightly excavated facet. There was apparently no contact between the fibula and calcaneum. The cuboid has about the same relative height as is found in the viverrines in general; but in correspondence with the flat distal end of the calcaneum its proximal surface is likewise considerably flattened. The navicular again exhibits a very decided resemblance to that of the Binturong, and differs sharply from the viverrine, herpestine, and euplerine sections of the family. In the Binturong, the posterior margin of the bone is divided by a deep notch or sulcus into two sub-equal projections. In *Herpestes*, *Crossarchus*, and *Eupleres*, no such sulcus exists, and the postero-internal angle is enlarged and elevated. In the fossil this sulcus is present, but not so deep as in the Binturong, yet the arrangement is essentially the same. No other part of the pes is known. The principal measurements are as follows:

	mm
Length of three posterior premolars and first two superior molars	18·
Length of superior sectorial	5·
Transverse diameter of superior sectorial	3·8
Length of first and second molars (outside)	6·7
Transverse diameter of first molar (anterior)	5·8
Transverse diameter of first molar (posterior)	5·9
Transverse diameter of second molar (anterior)	5·5
Transverse diameter of second molar (posterior)	4·5
Length of inferior dental series from anterior border of canine	30·5
Length of first lower molar	4·5
Length of second lower molar	3·7
Depth of jaw at anterior border of first molar	8·2
Length of centrum of third (?) lumbar vertebra	15·
Length of centrum of last lumbar vertebra	15·
Length of centrum of penultimate lumbar vertebra	17·

Length of centrum of axis including odontoid	16· mm
Length of centrum of third cervical	8·
Length of humerus	68·5
Transverse diameter of humerus (distal end)	16·5
Length of ulna (estimated)	71·
Length of radius	58·
Length of carpus and metacarpus (estimated)	24·
Length of phalanx, second row	10·
Length of pelvis	74·
Transverse diameter of ilium	12·
Length of femur	92·
Transverse diameter of proximal extremity	16·5
Transverse diameter of *caput femoris*	8·3
Transverse diameter at lesser trochanter	15·
Transverse diameter of distal extremity	16·
Antero-posterior diameter of condyles	12·
Length of patella	6·
Transverse diameter of patella	6·8
Length of tibia (estimated)	81·5
Transverse diameter of head of tibia	14·5
Antero-posterior diameter of head of tibia	11·

Discussion.—In the foregoing description of this family, frequent reference has been made to their relationship with the Viverridæ, the characters in which the two families resemble as well as differ from each other have been pointed out as far as they are known, and the position has been generally assumed that the one stands in direct ancestral relation to the other. I will now proceed to summarize the arguments upon which this assumption is based, but it is first necessary to observe that the idea is by no means a new one. Professor Marsh, in giving the name *Viverravus* to the species first described, expressed this relationship, although he did not follow it up with the necessary evidence to establish it upon a firm foundation. In my work on the "Comparative Anatomy of the Teeth" (1886), I gave utterance to the same view, but did not attempt a demonstration of the same. Flower and Lydekker, in "Mammals Living and Extinct," 1891, p. 539, state: "The North American genera *Miacis* and *Didymictis* (*Uintacyon* and *Viverravus*) are generally regarded as representing a separate family—Miacidæ—with affinities to both the Viverridæ and the Canidæ." In our paper on "The Ancestry of Certain Members of the Canidæ, the Viverridæ, and Procyonidæ" (Bull. Amer. Mus., 1899), Matthew and myself reiterated this opinion, and from a study of the skeleton of a species of *Viverravus* brought forward some evidence in its support.

From a consideration of the materials at present before us, it may be regarded as clearly established that there were at

least two generic types living in this country during the deposition of the Bridger sediments, the sum total of whose characters, as far as they can be at present ascertained, come nearer to the living Viverridæ than to any other known group of the Carnivora. These characters, moreover, not only do not interpose any difficulties in the way of deriving the one group from the other by direct descent, but they furnish just such a combination of resemblances and differences as we should be reasonably led to look for on *a priori* grounds, in the Eocene ancestors of the existing Viverridæ. The living representatives of this family include three and perhaps four widely divergent types, so different from each other that at various times they have been considered by some very good authorities to represent distinct family modifications. One of these, the Viverrinæ, for which there are excellent reasons to believe that they come nearest to the original stem form, has fossil representatives in the Upper Eocene of Europe, whose remains are indistinguishable generically from those living to-day. This fact indicates a most remarkable persistence or stability of structure which we are not at liberty to suppose began abruptly in the Upper Eocene, but must have, in some degree at least, belonged to its earlier Eocene progenitors. Now it is either a striking coincidence or a highly significant fact that this very character is one of the preëminently distinguishing features of *Viverravus*. We have already seen that it passes with but very little change from the Torrejon to the Bridger inclusive, or, in other words, it did not change more than specifically, during the deposition of between six and seven thousand feet of sediment. There is another fact which must not be lost sight of just here, and that is, that in the Eastern Hemisphere these forms appear abruptly in the upper stages of the Eocene, while in the Western Hemisphere they disappear quite as suddenly in the age preceding. So much, then, for the general considerations touching the possible relationship of the two groups.

Let us next inquire into the special or particular resemblances and differences which they present. In the *Viverravus-Viverra* series we note, (1) that the dental formula is identically the same in the two groups; (2) that the structure of the various teeth, including all the details of arrangement with respect to the component cusps, ridges, etc., is surprisingly similar; (3) that the skull of *Viverravus* exhibits the same more or less compressed, post-orbitally elongated form as that of the Viverrinæ; (4) that the atlas has the same arrangement of the perforations for the passage of the vertebral artery—a highly characteristic viverrine feature; (5) that the succeeding vertebræ are very similar in the two groups, including the long and powerful tail, which is still retained;

and (6) that there is such a general similarity in the structure of the limbs that one could easily have been derived from the other.

The main points of difference are not of a fundamental character, but relate to the assumption of modernized features, such as (1) increase in size of the brain; (2) development of tympanic into a large, two-chambered, otic bulla, with consequent modification of the contiguous cranial foramina and paroccipital process; (3) decrease in relative size of the lumbar vertebræ; (4) reduction in size of the deltoid crest of the humerus; (5) union of the scaphoid, lunar, and centrale of the carpus; (6) loss of third trochanter of the femur, and reduction in size of the lesser trochanter; (7) development of cnemial crest of tibia, and (8) grooving of astragalus and loss of fibular contact with the calcaneum. These characters, as we know from so many other lines, pertain to all the primitive Carnivora, and involve just such parts of the osteological structure as have been profoundly and progressively modified by development. Instead, therefore, of offering any difficulties in the way of the derivation of the Viverrinæ from *Viverravus*, they are of such a nature as one would reasonably assume to belong to the primitive type. The evidence, then, in favor of this derivation, as it at present stands, is strongly presumptive if not absolutely demonstrative. If well founded, it establishes for this phylum an antiquity greater than that of any group of living Carnivora thus far known.

The position of the genus *Oödectes* with reference to the living forms is not so clear. The possession of three true molars in the superior and inferior series would hardly have been expected in a Bridger representative, seeing that in *Viverravus* they had already been reduced to the modern formula as early as the Torrejon. The genus, therefore, can clearly have nothing whatever to do with the ancestry of the *Viverra* series. That it is viverrine in its affinities, however, is so strongly suggested by almost every feature of its structure that it cannot be consistently placed in any other group. Among living forms, it seems to bear a more decided resemblance to certain of the Paradoxures than to any other section of the family, although the relatively short, thick premolars, with the disposition to the development of internal cusps, recall very forcibly certain members of the Herpestinæ. This character, however, is also found in the Paradoxures. In the inferior premolars it is important to note that in their lack of development of a distinctively trenchant and sectorial character, they are well fitted to give rise to the various types of teeth of this group, even including members the most aberrant and highly modified in this respect; as *Arctogale* and *Arctictis*. Indeed, the skeletel parts, as far as they are preserved, show many significant resemblances to the Binturong. These are

especially noticeable in the ulna, femur, patella, navicular, calcaneum, and cuboid. These resemblances, however, may be accidental and deceptive, and until we can connect the two groups somewhat more closely in point of time, their relations cannot be regarded as finally settled.

In this connection I wish to draw attention to three genera described by Professor Marsh from various fragmentary materials (mostly teeth and portions of jaws), the validity of which is either questionable or the remains are insufficient to indicate their true position. They are as follows:

Triacodon fallax Marsh.*

The type of this genus and species, figure 36, consists of the anterior portion of a tooth crown of the first lower molar or sectorial, which agrees in every particular with the corresponding tooth of *Viverravus gracilis*. I therefore do not hesitate to refer it to this species. Professor Marsh erroneously supposed that it was an entire tooth of the premolar series, and this at first sight would seem possible, since the broken surface where the heel joins the trigon is worn in such a way as more or less to conceal the fracture. I give herewith a cut of the tooth seen from the inside.

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FIGURE 36.—A right lower sectorial of *Triacodon fallax* Marsh; inside view; natural size. (Type.)

A second species, *T. grandis*,† was also described by Professor Marsh, and this again is founded upon the trigon of a sectorial molar of some larger species of Carnivore, presumably *Limnocyon verus*, although the specimen agrees equally well with some other species, notably *Sinopa agilis*. A third species, *T. nanus*, is of the same character, and is referable to some small carnivorous or insectivorous species.

Ziphacodon rugatus Marsh.‡

37

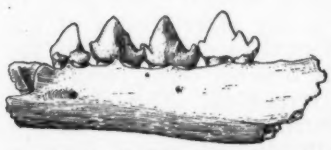

FIGURE 37.—Left lower jaw of *Ziphacodon rugatus* Marsh; outside view; three halves natural size. (Type.)

This genus and species was established upon the anterior portion of a lower jaw, figure 37, carrying the second and third premolars with the roots of the first and fourth, together with the alveolus for the canine and a part of that for the first incisor. As far as one is able to judge, this jaw fragment agrees perfectly with *Viverra-*

* This Journal, vol. ii, August, 1871, p. 15, separata.
† This Journal, vol. iv, August, 1872, p. 32, separata.
‡ This Journal, vol. iv, August, 1872, p. 25, separata.

vus gracilis. The principal points of similarity are seen in the two-rooted first premolar, which is characteristic of all the Bridger species of *Viverravus*, the form of the premolars, and the agreement in size. The name may, therefore, I think, be properly placed as a synonym of *V. gracilis.*

Harpalodon sylvestris Marsh.*

This small species of Carnivore was founded upon a fragment of a left lower jaw, figure 38, supporting the third and fourth premolars and a part of the crown of the first molar or sectorial, including the complete heel. The structure of the premolars agrees most nearly with those of *Uintacyon edax.* The heel of the sectorial is somewhat less trenchant, having the inner portion slightly developed so as to form an incipient basin. The jaw is broken below so as not to display its character very well, yet it has the appearance of being much more slender, though lacking the thick heavy structure of this latter species. When more fully known, this may prove to be a distinct form. With the present material, however, I am persuaded that the best course to pursue is to place it in the doubtful list, since there are no characters by which it can be properly placed or distinguished.

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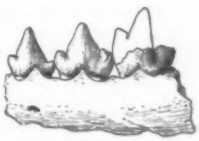

FIGURE 38. — Portion of left lower jaw of *Harpalodon sylvestris* Marsh; outside view; three halves natural size. (Type.)

A second species of this genus, *H. vulpinus*, founded upon a lower jaw fragment, figure 39, containing the last premolar, I think clearly belongs to *Viverravus gracilis*, and I have no hesitancy in placing it in this category.

Family *Palæonictidæ* Osborn and Wortman.

Palæonictidæ Osborn and Wortman, Bull. Amer. Mus. Nat. Hist., vol. iv, no. 1, 1892.

A family of little known, primitive Carnassidents placed ancestral to the Felines, ranging in time from the Wasatch to the Bridger inclusive, and characterized by the early and rapid reduction of the molar dentition, the short face, and cat-like lower jaw.

Of this family, three genera are known, of which *Palæonictis* comes from the Wasatch of Europe and America, *Amblyctonus* from the Wasatch of New Mexico, and *Ælurotherium* from the Bridger.

39

FIGURE 39.—Fragment of left lower jaw of *Harpalodon vulpinus* Marsh; outside view; three halves natural size. (Type.)

* This Journal, vol. iv, August, 1872, p. 25, separata.

A well-preserved anterior portion of a skull of *Palæonictis americanus* was secured by the writer in the Wasatch horizon of the Big Horn Basin, in 1891, which formed the basis of the description of this species and is the best specimen of the group thus far recovered. *Amblyctonus* is known from a few fragmentary remains of teeth and jaws only. No other skeletal parts have been found.

Æ lurotherium latidens Marsh.

Limnofelis latidens Marsh, this Journal, vol. iv, August, 1872; *Patriofelis leidyanus* Osborn and Wortman, Bull. Amer. Mus., vol. iv, no. 1, 1892; *Patriofelis leidyanus* Wortman, Bull. Amer. Mus., 1894, p. 164; *Æ lurotherium leidyanum* Adams, this Journal, June, 1896, p. 442.

Professor Marsh, in describing *Limnofelis latidens*, states: "A second very large Carnivore, but inferior to the preceding

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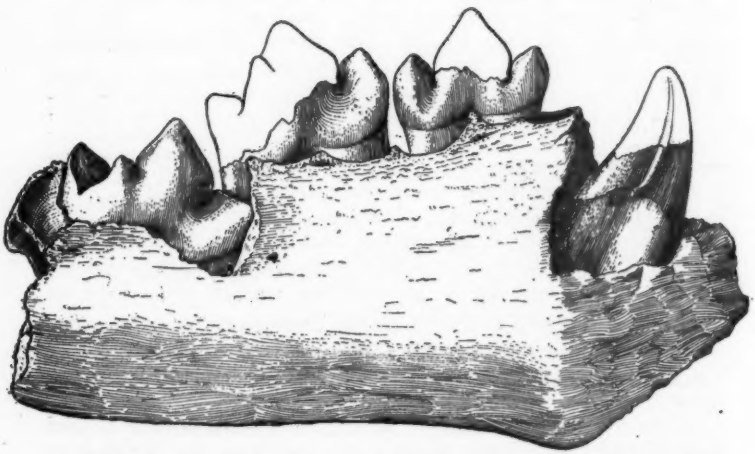

FIGURE 40.—Left lower jaw, with milk teeth and first permanent molar, of *Æ lurotherium latidens* Marsh; inside view; three halves natural size. (Type.)

in size, is indicated by a last upper premolar and probably by some other fragmentary remains. . . . . Another specimen apparently of this species is a left lower jaw of a young individual. It contains the canine and three (four) molars, the last of which is still nearly enclosed in the jaw." It is now evident that the fourth premolar above mentioned belongs to *Patriofelis ferox*, which was previously described by Professor Marsh; and that the second specimen, or that of the immature individual, figures 40, 41, is a member, not only of

another genus, but another family. It is therefore the type of the genus and species under consideration. The specimen consists of an incomplete mandibular ramus containing the deciduous canine, second and third deciduous molars, the alveolus for the first, and the crown of the first permanent molar, which was just being erupted. Immediately posterior to this tooth is seen a part of the bony crypt which lodged the imperfectly calcified germ of a second molar, so that the inferior molar and premolar formula can be determined. The three deciduous molars imply a like number of permanent premolars, and as there is evidence of no more than two molars, we may fairly assume that the number was two. The formula would then be I. (?), C. $\frac{0}{1}$, Pm. $\frac{3}{3}$, M. $\frac{2}{2}$.

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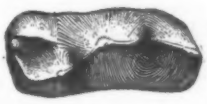

FIGURE 41. — Crown view of first lower molar of *Æ. latidens;* three halves natural size. (Type.)

The deciduous canine was not fully erupted and the point of the crown is missing. Like the corresponding milk tooth of the lion, the root is considerably compressed from side to side and of great antero-posterior diameter. The crown is small in comparison with the root, and the enamel extends much further down on the buccal than upon the lingual side of the crown. There is a deep vertical sulcus, flanked by a distinct ridge in front, on the inner face, the base of the crown, which is surrounded by a distinct cingulum.

The first deciduous molar, as indicated by its alveolus, is placed behind the canine without diastema, somewhat internal to the tooth line and slightly overlapping the second tooth. The tooth was small and single-rooted. The second tooth is abruptly larger; it is implanted by two strong roots and has a crown composed of a large, laterally compressed, central cusp, with strong anterior and posterior cusps. There is no basal cingulum. In structure, this tooth agrees very closely with that of the lion.

The crown of the third deciduous molar is much damaged and does not display its structure satisfactorily. Enough remains, however, to enable me to state that its crown was thoroughly sectorial in organization. The anterior blade is preserved and is rather short antero-posteriorly. The great proportional length which remains indicates without much doubt that there was a rather large heel and probably an internal cusp as well. In the milk sectorial of the lion both these elements are present; and as far as this tooth is preserved in the fossil, its resemblance to that of the cats is much more marked that it is to any other family of the Carnassidentia.

As a whole, the milk dentition of the fossil differs from that of both the Canidæ and the Viverridæ in having three instead of four milk molars; from the Hyænidæ in the larger canine, the small, single-rooted first molar, and the development of three strong cusps on the second. In the hyæna, the first deciduous molar is large and two-rooted, and the anterior basal cusp on the second is rudimental or wanting. As far, however, as we are able to judge, in its imperfectly preserved condition, it agrees perfectly with that of the cats.

The crown of the sectorial is of much interest, inasmuch as it exhibits a stage of development intermediate between that of *Palæonictis* of the Wasatch and *Dinictis* of the Oligocene. The three usual cusps of the trigon are present, but they are flattened and their edges drawn out to a much greater extent than in any other Carnassident of its time. The internal cusp is relatively small, has a very posterior position, and there is no evidence that the posterior shear between it and the anterior edge of the first superior molar was functional, which leads to the conclusion that this latter tooth was considerably reduced. The heel is composed of a single, rather large trihedral cusp, with the anterior edge produced forwards toward the base of the trigon, thus very strongly foreshadowing the trenchant heel of the corresponding tooth of *Dinictis*, *Nimravus*, and so many other Felines of the Oligocene and Miocene.

As already noted, a part of the bony crypt which served to lodge the germ of a second molar is to be seen just posterior to the sectorial. Aside from the important fact of demonstrating the existence of a second molar, it furnished the further information that this tooth was much reduced in size, which is of still greater moment. The jaw has greater vertical depth in front than behind, the symphysis is large, but there is no trace of a flange as in *Dinictis*. Altogether it may be remarked that it is just such a type as preceded that of the Sabre-tooth Tigers.

The measurements are as follows:

Length from anterior base of canine to posterior part of first permanent molar	59· mm
Length of second and third deciduous molars	33·
Length of first permanent molar	18·5
Depth of jaw at first deciduous molar	32·
Depth of jaw behind first permanent molar	23·5

This important type specimen was found by Mr. G. M. Keasby of the Yale party of 1871, in the Henry's Fork Bad Lands of the Bridger Basin, Wyoming.

Ælurotherium bicuspis sp. nov.

A second species of this genus is indicated by a first lower molar or sectorial tooth, figures 42, 43, of the left side. It is somewhat smaller than this tooth in *Æ. latidens* and differs further from it in the possession of two cusps on the heel instead of one, which gives it a more decidedly basin-shaped

42

43

FIGURE 42.—Left lower sectorial molar of *Ælurotherium bicuspis* Wortman; outside view. (Type.)
FIGURE 43.—Crown view of same.
Both figures are three halves natural size.

character. Of the two cusps comprising the heel the larger is median and the smaller is external. This species is more closely allied to *Palæonictis*, in which the heel of the first lower molar is tubercular.

The principal measurements are as follows:

Antero-posterior diameter	16·8^{mm}
Transverse diameter	8·5
Height of crown at middle cusp	12·

The specimen was found by L. LaMothe on Henry's Fork, Bridger Basin, Wyoming.

Discussion.—Doubtless some objection will be raised to the placing of this family in the Carnassidentia, and did we have the genus *Palæonictis* alone to consider, it could be possibly regarded as a more or less questionable procedure, since the development of the fourth superior premolar and the first inferior molar into highly specialized carnassial teeth, to the exclusion of all the others, had not reached quite that degree of perfection displayed by either the contemporaneous viverrine or canine phylum; but at the same time, the tendency in this direction was so clearly evident as to leave no room for doubt that the genus should be arranged with those forms which finally developed the typical sectorial dentition of the modern Carnassidentia. There seems, moreover, to be entire unanimity of opinion that *Ælurotherium* is not only a member of the Palæonictidæ, but is the direct descendant of

Palæonictis. If this is true—and it would seem to be a very probable assumption from the evidence thus far obtained*—it then follows that the whole series are true Carnassidents, since the first lower molar of the Bridger species is practically as well developed and as exclusively a sectorial as it is in any of the Oligocene Felids.

The genetic relationship of *Ælurotherium* to the Oligocene Felidæ is a matter of the greatest moment, for the reason that, if once established, it gives us the long sought key to the solution of the problem of feline ancestry. Although the material upon which our knowledge at present rests is scarce and fragmentary, and the evidence correspondingly meager and incomplete, yet such as this affords appears to be of neither an indifferent character nor uncertain significance. We have already seen (1) that the milk dentition of the lower jaw is surprisingly feline in the make-up; (2) that the molar and premolar formula for the inferior series is the same as in certain of the Oligocene types, notably *Dinictis;* (3) that the structure of the molars and premolars coincides almost exactly with those forms, and (4) that the form of the lower jaw exhibits unmistakable evidences of relationship. The specimens do not afford any evidence whatever of a contrary nature, and until such is forthcoming we must look upon this source of feline origin as not only possible but extremely probable.

If the conclusions herein set forth are well founded, it follows that in the Bridger epoch there were clearly established three of the main lines of modern Carnassident descent, a fact which in itself implies an origin at a much earlier date. Indeed, as the evidence accumulates we are forced to conclude that the beginnings of these phyletic lines are incomparably more ancient than we had formerly thought possible.

*See Ancestry of the Felidæ, Bull. Amer. Mus. Nat. Hist., 1892, p. 94, in which I fully discussed this subject.

[To be continued.]

ART. XXIV.—*On the Separation of the Least Volatile Gases of Atmospheric Air, and their Spectra;* by G. D. LIVEING, M.A., Sc.D., F.R.S., Professor of Chemistry in the University of Cambridge, and JAMES DEWAR, M.A., LL.D., F.R.S., Fullerian Professor of Chemistry, Royal Institution, London.

[Read before the Royal Society of London, June 20, 1901.]

OUR last communication to the Society* related to the *most* volatile of the atmospheric gases; that which we now beg leave to offer relates to the *least* volatile of those gases. The former were obtained from their solution in liquid air by fractional distillation at low pressure, and separation of the condensible part of the distillate by cooling it in liquid hydrogen. The latter were, in the first instance, obtained from the residue of liquid air, after the distillation of the first fraction, by allowing it to evaporate gradually at a temperature rising only very slowly. The diagram, fig. 1, will make the former process intelligible. *A* represents a vacuum-jacketed vessel, partly filled with liquid air, in which a second vessel, *B*, was immersed. From the bottom of *B* a tube, *a*, passed up

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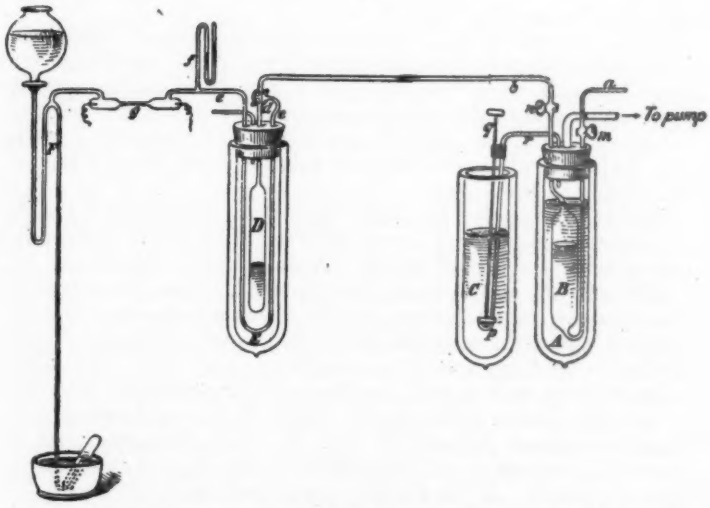

* Proc. Roy. Soc., vol. lxvii, p. 467; this Journal, xi, 154.

through the rubber cork which closed *A*, and from the top of *B* a second tube, *b*, passed through the cork and on to the rest of the apparatus. Each of these tubes had a stopcock, *m* and *n*, and the end of tube *a* was open to the air. A wider tube also passed through the cork of *A* and led to an air-pump, whereby the pressure above the liquid air in *A* was reduced, and the temperature of the liquid reduced by the consequent evaporation. To keep the inner vessel, *B*, covered with liquid, a fourth tube, *r*, passed through the cork, and its lower end, furnished with a valve, *p*, which could be opened and closed by the handle *q*, dipped into liquid air contained in the vessel *C*. As the pressure above the liquid in *A* was less than that of the atmosphere, on opening the valve *p* some of the liquid air was forced through *r* into *A* by the pressure of the atmosphere, and in this way the level of liquid in *A* maintained at the required height.

Since *B* was maintained at the temperature of liquid air boiling at reduced pressure, the air it contained condensed on its sides, and when the stopcock *n* was closed and *m* opened more air passed in through the open end of *a*, and was in turn condensed. In this way *B* could be filled completely with liquid air, the whole of the most volatile gases being retained in solution in the liquid.

The tube *b*, passing from the top of *B*, was connected with a three-way stopcock *d*, by which it could be put in communication with the closed vessel, *D*, or with the tube *e*, and by which also *D* and *e* could be connected. The tube *e* passed down nearly to the bottom of the vacuum-jacketed vessel *E*, and out again through the cork; and so on to a gauge *f*, and through a sparking tube *g* to a mercury pump *F*.* The stopcock *n* being still closed, the whole of the apparatus between *n* and the pump, including the vessel *D*, was exhausted, and liquid hydrogen introduced into *E*. The three-way cock *d* was then turned so as to connect *b* with *D*, and close *e*, and then *n* opened. *B* was thereby put in communication with *D*, which was at a still lower temperature than *B*, and the gas dissolved in the liquid in *B*, along with some of the most volatile part of that liquid, distilled over, and the latter condensed in a solid form in *D*. When a small fraction of the liquid in *B* had thus distilled, the stopcock *d* was turned so as to close the communication between *D* and *b* and open that between *D* and *e*. Gas from *D* passed into the vacuous tubes, but in so doing it had to pass through the portion of *e* which was immersed in liquid hydrogen, so that condensible matter carried forward by the stream of gas was frozen out.

* The Sprengel in figure is simply diagrammatic.

For separating the least volatile part of the gases, the vessel *E*, with its contents, was dispensed with, and the tube *b* made to communicate directly with that connected with the gauge, sparking tube, and pump; and generally several sparking tubes were interposed between the gauge and pump, so that they could be sealed off successively. The bulk of the liquid in *B* consisted of nitrogen and oxygen. These were allowed gradually to evaporate, the temperature of *B* being still kept low so as to check the evaporation of the gases less volatile than oxygen. When a great part of the nitrogen and oxygen had thus been removed, the stopcock *n* was closed, and the tubes partially exhausted by the pump, electric sparks passed through *g*, and the gases examined spectroscopically. More gas was then evaporated from *B*, and the spectroscopic examination repeated from time to time.

The general sequence of spectra, omitting those of nitrogen, hydrogen, and compounds of carbon, which were never entirely removed by the process of distillation alone, was as follows: The spectrum of argon was first noticed, and then as the distillation proceeded the brightest rays, green and yellow, of krypton appeared, and then the intensity of the argon spectrum waned, and it gave way to that of krypton until, as predicted by Runge, when a Leyden jar was in the circuit, the capillary part of the sparking tube had a magnificent blue color, while the wide ends were bright pale yellow. Without a jar the tube was nearly white in the capillary part, and yellow about the poles. As the distillation proceeded, the temperature of the vessel containing the residue of liquid air being allowed to rise slowly, the brightest of the xenon rays began to appear, namely, the green rays about λ 5420, 5292, and 4922, and then the krypton rays soon died out and were superseded by the xenon rays. At this stage the capillary part of the sparking tube is, with a jar in circuit, a brilliant green; and is still green, though less brilliant, without the jar. The xenon formed the final fraction distilled.

Subsequently an improved form of apparatus was used for the fractionation. It is represented in fig. 2. A gasholder containing the gases to be separated, that is to say, the least volatile part of atmospheric air, was connected with the apparatus by the tube *a*, furnished with a stopcock *c*. This tube passed on to the bulb *B*, which in turn communicated through the tube *b* and stopcock *d* with a sparking tube, and so on through the tube *e*, with a mercurial pump. Stopcock *d* being closed and *c* opened, gas from the holder was allowed to pass into *B*, maintained at low temperature, and there condensed in the solid form. Stopcock *c* was then closed and *d* opened, and gas from *B* allowed to pass into the exhausted tubes between

B and the pump. The tube *e* was partly immersed in liquid air in order to condense vapor of mercury, which would otherwise pass from the pump into the sparking tube. The gas passing into the sparking tube would, of course, have a pressure corresponding to the temperature of *B*, and this was further ensured by making the connecting tube pass through the liquid in which *B* was immersed. The success of the operation of separating all the gases which occur in air and which boil at different temperatures depends on keeping the

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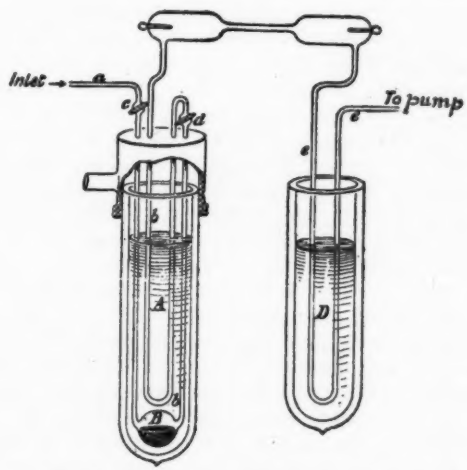


temperature of *B* as low as possible, as will be seen from the following consideration :—

The pressure p, of a gas G, above the same material in the liquid state, at temperature T, is given approximately by the formula

$$\log p = A - \frac{B}{T},$$

where A and B are constants for the same material. For some other gas G' the formula will be

$$\log p_1 = A_1 - \frac{B_1}{T},$$

and

$$\log \frac{p}{p_1} = A - A_1 + \frac{B_1 - B}{T}.$$

Now for argon, krypton, and xenon respectively the values of A are 6·782, 6·972, and 6·963, and those of B are 339, 496·3,

and 669·2; so that for these substances and many others $A-A_1$ is always a small quantity, while $\frac{B_1-B}{T}$ is considerable and increases as T diminishes. Hence the ratio of p to p_1 increases rapidly as T diminishes, and by evaporating all the gases from the solid state and keeping the solid at as low a temperature as possible, the gas first coming off consists in by far the greatest part of that which has the lowest boiling point, which in this case is nitrogen, and is succeeded, with comparative abruptness, by the gas which has the next higher boiling point. The change from one gas to another is easily detected by examining the spectrum in the sparking tube, and the reservoirs into which the gases are pumped can be changed when the spectrum changes, and the fractions separately stored. Or, if several sparking tubes are interposed in such a way as to form parallel communications between the tubes *b* and *e*, any one of them can be sealed off at any desired stage of the fractionation.

The variation of the spectra of both xenon and krypton with variation in the character of the electric discharge is very striking, and has already been the subject of remark, in the case of krypton, by Runge, who has compared krypton with argon in its sensitiveness to changes in the electric discharge. Runge distinguishes krypton rays which are visible without a jar and those which are only visible with a jar discharge. The difference in the intensity of certain rays, according as the discharge is continuous or oscillatory, is no doubt very marked, but, with rare exceptions, we have found that the rays which are intensified by the oscillatory discharge can be seen with a continuous discharge when the slit of the spectroscope is wide. Runge used a grating, whereas we have, for the sake of more light, used a prism spectroscope throughout, and were therefore able to observe many more rays.

There is one very remarkable change in the xenon spectrum produced by the introduction of a jar into the circuit. Without the jar xenon gives two bright green rays at about λ 4917 and λ 4924, but on putting a jar into the circuit they are replaced by a single still stronger ray at about λ 4922. In no other case have we noticed a change so striking as this on merely changing the character of the discharge. Changes of the spectrum by the introduction of a jar into the circuit are, however, the rule rather than the exception, and there are changes in the spectrum of krypton which seem to depend on other circumstances. In the course of our examination of many tubes filled with krypton in the manner above indicated, we have found some of them to give with no jar the green ray λ 5571, the yellow ray λ 5871, and the red ray λ 7600 very

bright, while other rays are very few, and those few barely visible. Putting a jar into the circuit makes very little difference; the three rays above mentioned remain much the brightest, nearly, though not quite, so bright as before, and the blue rays, so conspicuous in other tubes, though strengthened by the use of the jar, are still very weak. In other tubes the extreme red ray is invisible, the rays at λ 5571 and 5871 absolutely, as well as relatively, much feebler, while the strong blue rays are bright, even brighter than the green and yellow rays above named. In one tube the blue rays could be seen, though not the others. This looks very much as if two different gases were involved, but we have not been able to assure ourselves of that. The case seems nearly parallel with that of hydrogen. There are some hydrogen tubes which show the second spectrum of hydrogen very bright, and others which show only the first spectrum; the second spectrum is enfeebled or extinguished by introducing a jar into the circuit, while the first spectrum is strengthened; and the conditions which determine the appearance of the ultra-violet series of hydrogen rays have not yet been satisfactorily made out.

It is to be noted that putting the jar out of circuit does not in general immediately reduce the brightness of the rays which are strengthened by the jar discharge. Their intensity fades gradually, and is generally revived, more or less, by reversing the direction of the current, but this revival gets less marked at each reversal until the intensity reaches its minimum. The rays strengthened by the jar discharge also sometimes appear bright, without a jar, on first passing the spark when the electrodes are cold, and fade when the electrodes get hot, reappearing when the tube has cooled again. Moreover, if the discharge be continued without a jar, the resistance in the krypton tubes increases rather rapidly, the tube becomes much less luminous and finally refuses to pass the spark. With an oscillatory discharge the passage of the spark and the brightness of the rays are much more persistent. This seems to point to some action at the electrodes, which is more marked in the case of krypton than in that of xenon.

The wave-lengths of the xenon and krypton rays in the tables below were determined, in the visible part of the spectrum, with a spectroscope having three white flint-glass prisms of 60° each, by reference to the spark spectrum of iron, except in the cases of the extreme red ray of krypton, which was referred to the flame spectrum of potassium, and its fainter neighbor, which we saw but did not measure. The indigo, violet, and ultra-violet rays were measured in photographs, taken with quartz lenses and two calcite prisms of 60° each. The spectrum of the iron spark was photographed at the same time as

that of the tube, the former being admitted through one-half of the slit, and the latter through the other half.

The xenon spectrum is characterized by a group of four conspicuous orange rays of about equal intensities, a group of very bright green rays of which two are especially conspicuous, and several very bright blue rays. The only list of xenon rays we have seen is that published by Erdmann, with which our list does not present any close agreement except as to the strongest green lines. The number of xenon rays we have observed is very considerable, and some of them lie very near to rays of the second spectrum of hydrogen, but inasmuch as these rays are more conspicuous with a jar in circuit than without, which is not the character of the second spectrum of hydrogen, and, moreover, many of the brightest of the hydrogen rays are absent from the spectrum of the tubes, we conclude that these rays are not due to hydrogen. Certain rays, which we have tabulated separately, have been as yet observed in only one tube: they include a very strong ultra-violet ray of unknown origin, and due either to some substance other than xenon, or to some condition of the tube which has not been repeated in the other tubes.

Our krypton rays agree much more closely with Runge's list, but outnumber his very considerably, as might be expected when prisms were used instead of a grating. Prisms, of course, cannot compete with gratings in the accuracy of wave-length determinations. We think that the krypton used by Runge must have contained some xenon, and that the rays for which he gives the wave-lengths 5419·38, 5292·37, and 4844·58 were really due to xenon, as they are three of the strongest rays emitted by our xenon tubes, and are weak in, and in some cases absent from, the spectra of our krypton tubes.

Tables of the approximate Wave-lengths of Xenon and Krypton Rays.

Rays observed only with a Leyden jar in circuit have a * prefixed, those observed only when no Leyden jar was in circuit have a † prefixed.

The intensities indicated are approximately those of the rays when a jar is in circuit, except in the case of the two rays to which a † is prefixed, which are not seen when a jar is in circuit. Rays which are equally intense whether a jar is in circuit or not have a ‖ prefixed to the number indicating their intensities; those which are less intense with a jar than without have a $<$ prefixed to the number expressing their intensities. The rest are, in general, decidedly more intense with a jar than without.

Xenon Rays.

Wave-length.	Intensity.	Wave-length.	Intensity.	Wave-length.	Intensity.	Wave-length.	Intensity.
*6596	4	5025	<1	4286	3	3870	2
* 14	1	4988	4	72	3	62	2
6472	‖ 1	72	2	69	3	58	2
6358	1	† 24	†4	63	2	55	1
45	3	* 22	8	51	3	50	2
20	‖ 1	† 17	†4	45	10	49	1
02	1	4890	3	39	8	42	4
6278	3	87	—	27	1	29	1
71	3	84	4	23	5	26	1
6183	‖ 1	83	—	15	10	24	1
81	‖ 1	76	4	14	6	15	1
66	‖ 1	44	10	09	8	11	3
6097	6	30	‖ 1	04	‖ 1	07	1
51	6	23	3	01	1	01	1
36	5	* 18	3	4198	1	3792	1
5976	6	07	⟋1	93	‖ 6	87	1
72	—	4793	1	81	10	83	1
46	2	87	2	76	1	81	6
35	<1	79	2	72	1	76	3
06	1	69	2	63	3	73	1
5895	‖ 1	40	1	59	3	70	1
76	‖ 1	34	<1	46	3	66	1
56	‖ 1	31	1	42	1	63	2
25	2	23	1	32	2	62	1
17	—	14	1	21	1	57	1
5777	4	4698	‖ 3	12	2	46	3
59	4	4677 }	band of	09	6	37	1
51	5	to }	close	06	3	31	2
27	4	4668 }	lines	4000	2	21	3
20	4	52	4	99	3	17	2
00	6	34	2	93	1	12	2
5668	4	24	<2	79	<1	08	1
60	1	16	3	74	1	3689	1
17	—	02	8	60	1	77	3
09	1	4592	3	58	6	73	2
5583	1	86	‖ 5	50	6	64	1
73	1	77	3	44	1	62	2
32	4	56	2	43	1	58	1
5473	3	45	3	37	6	55	2
61	3	41	3	29	1	50	1
* 51	1	35	2	25	3	45	6
39	3	25	‖ 5	21	1	41	2
20	10	22	1	3902	3	32	2
5372	6	00	‖ 1	94	2	24	10
* 68	1	4486	1	91	3	16	1
39	6	81	5	86	1	13	4
13	1	71	2	81	1	10	2
09	1	62	10	75	1	07	4
5292	10	49	6	73	2	02	1
62	2	40	1	57	‖ 1	3597	8
60	2	34	2	55	4	84	8
40	—	15	8	51	<6	80	8
27	1	07	3	44	3	65	4
02	1	4396	4	39	1	56	3
5192	6	93	4	26	1	53	5
89	3	86	3	23	6	43	6
85	3	75	4	15	1	23	4
79	3	69	4	08	4	10	2
26	3	56	1	06	1	04	1
23	1	43	1	3803	1	01	4
07	3	37	3	94	3	3468	2
5080	2	31	10	85	3	61	1
68	5	22	3	80	3	54	1
52	1	11	3	77	3		
45	6	4297	3				

Wave-lengths of rays of unknown origin observed in the spectrum of one tube containing xenon but not present in the spectrum of other tubes :—

Wave-length.	Intensity.	Wave-length.	Intensity.	Wave-length.	Intensity.	Wave-length.	Intensity.
4589	—	4063	—	3890	1	3741	4
4071	1	11	1	72	1	3684	10
67	1	3998	1	3797	5	3573	2

Krypton Rays.

Wave-length.	Intensity.	Wave-length.	Intensity.	Wave-length.	Intensity.	Wave-length.	Intensity.
7600	8	5186	1	4387	3	3859	1
‡7587	2	72	1	76	3	58	1
6771	1	66	5	63	2	47	1
6578	1	43	4	56	12	44	2
42	3	26	6	23	2	42	1
11	2	5087	3	20	‖ 8	39	1
6487	3	78	1	19	‖ 3	37	2
58	<1	73	2	18	3	17	2
51	3	57	3	01	7	06	2
20	<4	34	1	4293	10	05	3
6305	3	23	4	83	‖ 3	3784	10
6170	2	14	‖ 2	74	‖ 4	79	8
6095	1	4980	1	69	3	72	4
82	1	60	1	60	1	59	2
56	2	46	1	56	1	55	6
21	1	03	2	51	5	46	6
11	2	4847	2	37	4	42	6
5992	3	45	2	4185	3	36	3
5873	1	* 33	5	72	1	34	4
71	<10	26	3	45	8	22	5
5771	2	12	3	40	2	19	10
53	2	4766	10	4119	3	15	1
5690	5	63	3	09	6	3691	1
82	5	39	10	4099	8	87	5
50	1	4694	3	89	8	81	7
32	2	80	5	65	7	70	7
5571	<10	59	8	58	6	67	1
63	3	50	1	45	4	64	3
53	1	35	6	38	2	61	3
44	1	20	8	08	2	54	10
23	2	15	6	05	1	49	3
06	2	10	3	3997	3	38	4
00	2	4598	1	94	6	32	10
5483	1	93	2	88	2	24	1
46	2	83	4	65	1	08	6
29	1	77	8	55	2	00	6
24	1	25	3	39	1	3590	3
03	1	05	‖ 2	28	3	74	1
5319	1	4490	2	21	8	54	2
05	1	75	6	18	2	45	6
5278	1	64	‖ 3 pair	13	6	03	2
29	1	54	‖ 1	07	6	3489	2
18	1	37	6	01	1	70	1
15	1	32	6	3896	8	60	3
* 09	5	23	2	76	7		
03	1	00	1	62	1		

‡ This is taken from Runge's number for the wave-length omitting the fraction.

Art. XXV.—*The Estimation of Calcium, Strontium, and Barium, as the Oxalates;* by Charles A. Peters.

[Contributions from the Kent Chemical Laboratory of Yale University—CI.]

A former article from this laboratory* describes the conditions under which oxalic acid may be titrated by potassium permanganate in the presence of hydrochloric acid, and states that the extra consumption of permanganate which ordinarily takes place when oxalic acid is titrated by permanganate in the presence of hydrochloric acid, may be prevented by the addition of a manganous salt. This fact led to the idea of effecting the solution of the alkaline earth oxalates in hydrochloric acid and titrating the free oxalic acid with permanganate in the presence of a manganous salt, and so to the study of the conditions under which precipitates of strontium and barium oxalates could be obtained sufficiently insoluble for quantitative purposes, the conditions under which calcium oxalate is insoluble being already known.

The permanganate solution was standardized against freshly recrystallized ammonium oxalate, and on oxalic acid, the standards agreeing.

Calcium Oxalate.

It is well known that calcium may be estimated by treating the precipitated oxalate with sulphuric acid and titrating by permanganate the oxalic acid set free.† In the work described in the present article, the precipitate of calcium oxalate has been dissolved in hydrochloric acid and the oxalic acid titrated by permanganate in the presence of a manganous salt. The process was as follows: The boiling hot solution of calcium chloride was precipitated with ammonium oxalate, allowed to stand 12 hours, and the supernatant liquid decanted on asbestos. The precipitate was washed two or three times by decantation with 50–100$^{cm^3}$ of cold water and brought on the felt. The crucible containing the precipitate was returned to the beaker, 100–200$^{cm^3}$ of water were added, together with 5–10$^{cm^3}$ of strong hydrochloric acid and 0·5–1·0 gm. of manganous chloride, and the oxalic acid was titrated at a temperature of 35°–45°. The results given in Table I are obviously excellent, and show that calcium, taken as the oxalate, may be estimated by potassium permanganate in the presence of hydrochloric acid and a manganous salt.

Extended washing with hot water, however, is to be avoided after the precipitant, ammonium oxalate, has been removed.

* Gooch and Peters, this Journal, vii, 466.

† Mohr, Titrirmethode, 6te Aufl., s. 227.

TABLE I.

CaO, taken as $CaCl_2$. grm.	Ammonium oxalate. grm.	Volume at precipitation. cm^3.	CaO found. grm.	Error. grm.
0·0656	0·3	100	0·0657	+0·0001
"	"	100	0·0656	0·0000
"	"	150	0·0658	+0·0002
"	"	100	0·0655	−0·0001
0·0985	0·5	175	0·0981	−0·0004
0·1313	0·6	150	0·1315	+0·0002
"	"	200	0·1315	+0·0002

In one experiment, for example, in which the precipitate, on the felt, was washed fourteen times with portions of about 50^{cm^3} each of hot water, each portion bleached from 2–6 drops of approximately one-tenth normal permanganate, making a total loss of 0·0034 grm. of calcium oxide.

Strontium Oxalate.

Souchay and Lenssen* state that strontium oxalate is soluble in 12,000 parts of water. This fact seemed sufficient to warrant the study of the quantitative separation of strontium as the oxalate. In the work which follows strontium oxalate has been precipitated both in alcoholic solution and in water solution, and for convenience these two conditions of precipitation will be discussed separately. All the strontium salts, of established purity, were standardized by precipitation with sulphuric acid in a solution containing at least one-half its volume of alcohol, and with some solutions confirmatory standards were also obtained by evaporization with sulphuric acid.

Precipitation in Alcoholic Solution.—To determine the completeness of the precipitation in alcoholic solution strontium nitrate was precipitated by ammonium oxalate in a solution containing one-third of its volume of alcohol, the mixture was allowed to stand over night, the liquid was filtered off on asbestos, and the precipitate was treated in the capped filtering crucible with sulphuric acid, ignited, and weighed as the sulphate.

The results are given in Table II.

It is plain from the results recorded in this table that the precipitation of even small amounts of the strontium salt from a solution containing one-third of its volume of alcohol is practically complete.

To determine the minimum amount of alcohol necessary for the complete precipitation of the strontium oxalate, experi-

* Ann. der Chem. (Liebig), cii, 35.

TABLE II.

SrO, taken as $Sr(NO_3)_2$. grm.	Ammonium oxalate. grm.	Volume at precipitation. cm^3.	Volume of alcohol.	SrO, found as $SrSO_4$. grm.	Difference. grm.
0·2434	0·8	180	$\frac{1}{3}$	0·2440	+0·0006
0·2434	0·8	"	"	0·2437	+0·0003
0·0022	0·2	100	"	0·0022	0·0000
0·0013	0·2	"	"	0·0014	+0·0001
0·0004	0·04	"	"	0·0004	0·0000

ments were made using varying proportions of 85 per cent alcohol with different amounts of ammonium oxalate, and the filtrates from such experiments were tested for strontium by the addition of more alcohol.

The results are given in Table III.

TABLE III.

SrO, present as $Sr(NO_3)_2$. grm.	Ammonium oxalate. grm.	Volume of liquid. cm^3.	Proportion of 85% alcohol.	SrO found in filtrate, weighed as $SrSO_4$. grm.
0·1	0·4	100	$\frac{1}{5}$	0·0000
"	"	"	$\frac{1}{10}$	0·0000
"	"	"	$\frac{1}{20}$	0·0004
0·1	0·2	"	$\frac{1}{5}$	0·0000
"	"	"	$\frac{1}{10}$	0·0009
"	"	"	$\frac{1}{20}$	0·0020
0·1	0·1	"	$\frac{1}{5}$	0·0002

The results in Table III show that when a moderate excess of ammonium oxalate is present, a volume of 85 per cent alcohol, amounting to one-fifth of the whole, is sufficient to complete the precipitation of the strontium as the oxalate.

The conditions under which strontium oxalate is insoluble having been determined, the process for the volumetric estimation of strontium was carried out as follows: The hot solution of a strontium salt was precipitated with ammonium oxalate, 85 per cent alcohol, amounting to from one-fifth to one-third the total volume, was added, the mixture was allowed to stand over night, and the clear liquid was decanted on an asbestos filter. The precipitate was washed with a mixture of equal parts of 85 per cent alcohol and water, transferred to the filter, dried in the filtering crucible over a flame to free it from alcohol, returned to the beaker previously dried, treated with sulphuric acid, or with 5–10$^{cm^3}$ of hydrochloric acid (in the latter case 0·5–1·0 gm. of a manganous salt being added) and the liberated oxalic acid was titrated by permanganate. The results obtained by this method are accurate and are given in Table IV.

TABLE IV.

Volume during titration 150–250$^{cm^3}$.

SrO, taken as $Sr(NO_3)_2$. grm.	Ammonium oxalate. grm.	Volume at precipitation. cm^3.	Proportion of 85% alcohol.	Acid present during titration.	SrO found. grm.	Error. grm.
0·0974	0·4	100	$\frac{1}{2}$	HCl	0·0973	−0·0001
"	"	"	"	"	0·0983	+0·0009
"	"	"	"	"	0·0975	+0·0001
"	0·8	"	"	"	0·0981	+0·0007
0·1948	0·4	200	"	"	0·1943	−0·0005
"	0·8	"	"	"	0·1942	−0·0006
0·0974	0·4	100	$\frac{1}{2}$	H_2SO_4	0·0970	−0·0004
"	"	"	$\frac{1}{5}$	"	0·0977	+0·0003
"	"	"	"	"	0 0976	+0·0002
0·1948	0·6	150	"	"	0·1938	−0·0010

In the last experiment in which a comparatively large amount of strontium salt was present and the dilution low, there is a slight tendency towards a minus error due probably to the occlusion of some oxalic acid by the strontium sulphate formed. This phenomenon would favor titration at greater dilution when sulphuric acid is used to liberate the oxalic acid from large amounts of strontium oxalate.

Precipitation in Water Solution.—In order to determine the degree of precipitation of strontium salts in water solution, 0·0974 grm. of strontium oxide, taken as the nitrate, was precipitated by ammonium oxalate, the mixture was allowed to stand over night, filtered on asbestos, the precipitate was washed with water containing one-half of its volume of 85 per cent alcohol, treated in the capped crucible with a few drops of sulphuric acid, ignited, and weighed as the sulphate. The result gave 0·0973 grm. of strontium oxide. The precipitation, therefore, of strontium oxalate, in water solution with a sufficient excess of ammonium oxalate present, is practically complete.

To determine the amount of ammonium oxalate necessary for the precipitation of strontium salts in water solution, experiments were made in which strontium oxalate was precipitated in the presence of varying amounts of ammonium oxalate, allowed to stand over night, the clear liquid was decanted on asbestos, and the precipitate was washed two or three times with 10–20$^{cm^3}$ of cold water. The results obtained by the estimation of the oxalic acid by permanganate show that an amount of ammonium oxalate several times larger than that required for the theoretical formation of strontium oxalate is necessary for the separation of the strontium oxalate. The experiments are recorded in Table V.

TABLE V.

SrO, taken as $Sr(NO_3)_2$. grm.	Ammonium oxalate. grm.	Volume at precipitation. cm^3.	Acid present during titration.	SrO found. grm.	Error. grm.
0·0487	0·064	100	H_2SO_4	0·0441	−0·0046
"	0·0768	"	"	0·0465	−0·0022
"	0·16	"	"	0·0488	−0·0001
0·0974	0·128	"	"	0·0939	−0·0025
"	0·16	"	"	0·0959	−0·0015
"	0·32	"	"	0·0975	+0·0001

The solvent action of a large amount of water on a precipitate of strontium oxalate was tested by washing a precipitate equivalent to 0·0974 grm. of the oxide with 150$^{cm^3}$ of cold water. The precipitate, when weighed as the sulphate, showed a loss of 0·0033 grm. as the oxide, which amount was subsequently recovered from the filtrate by the addition of ammonium oxalate and alcohol. Plainly excessive washing with water is to be avoided. In the estimation, therefore, of strontium when precipitated as the oxalate in water solution the amount of water used in washing was limited. It was found that 30–40$^{cm^3}$ of water judiciously applied was sufficient to wash out the ammonium salt without producing appreciable solvent effect upon the strontium oxalate.

The process of treatment was similar to that used in the precipitations from alcoholic solution, excepting that no alcohol was added to the solution, that the washing was effected with a limited amount of water, and that, there being no alcohol present to affect the titration, the precipitate was not dried before treatment with permanganate. The results are given in Table VI.

TABLE VI.

SrO, taken as $Sr(NO_3)_2$. grm.	Ammonium oxalate. grm.	Volume at precipitation. cm^3.	Acid present during titration.	SrO found. grm.	Error. grm.
		A			
0·0974	0·5	100	H_2SO_4	0·0966	−0·0008
"	"	"	"	0·0985	+0·0011
"	"	"	"	0·0977	+0·0003
"	"	"	"	0·0963	−0·0011
"	0·8	"	"	0·0981	+0·0007
"	"	"	"	0·0966	−0·0008
"	1·0	"	"	0·0965	−0·0009
"	2·0	"	"	0·0963	−0·0011
"	"	"	"	0·0970	−0·0004
0·0778	0·5	"	"	0·0792	+0·0014
"	"	"	"	0·0767	−0·0011
"	"	"	"	0·0776	−0·0002
"	"	"	"	0·0776	−0·0002
0·0974	0·8	250	"	0·0973	+0·0001
"	2·0	"	"	0·0975	−0·0001

SrO, taken as $SrCl_2$. grm.	Ammonium oxalate. grm.	Volume at precipitation. cm^3.	Acid present during titration.	SrO found. grm.	Error. grm.
		B			
0·0974	0·8	100	HCl	0·0971	−0·0003
"	"	"	"	0·0980	+0·0006
"	"	"	"	0·0975	+0·0001
"	"	"	"	0·0980	+0·0006
"	"	"	"	0·0973	−0·0001
"	"	"	"	0·0978	+0·0004
		C			
0·2425	0·384	125	H_2SO_4	0·2376	−0·0049
0·2436	"	"	"	0·2402	−0·0034
"	0·64	"	"	0·2411	−0·0025
"	0·8	"	"	0·2367	−0·0069
"	2·0	"	"	0·2376	−0·0060
"	"	"	"	0·2402	−0·0034
		D			
0·2436	0·8	250	H_2SO_4	0·2443	+0·0007
"	"	"	"	0·2446	+0·0010
"	2·0	"	"	0·2440	+0·0004
"	"	"	"	0·2431	−0·0005
		E			
0·2436	0·8	500	H_2SO_4	0·2396	−0·0040
"	2·0	"	"	0·2403	−0·0033
"	2·0	"	"	0·2413	−0·0023
"	4·0	"	"	0·2410	−0·0026
"	8·0	"	"	0·2407	−0·0029
0·4872	2·0	"	"	0·4837	−0·0035
"	4·0	"	"	0·4855	−0·0017
0·5430	5·0	"	"	0·5422	−0·0008
0·4579	10·0	"	"	0·4554	−0·0025
0·7307	5·0	"	HCl	0·7262	−0·0045

In the experiments recorded in section A of Table VI, the strontium oxalate was treated with sulphuric acid and titrated at 80°, the volume being 200–300$^{cm^3}$; while in the experiments given in section B, the precipitate was treated with hydrochloric acid and titrated at 35°–45°, at a volume of 100–200$^{cm^3}$, after the addition of 0·5–1·0 grm. of manganous chloride. The results show that 0·1 grm. of strontium salt, calculated as the oxide, may be estimated as the oxalate with a fair degree of accuracy when precipitated in 100–250$^{cm^3}$ of water by a sufficient excess of ammonium oxalate. In the experiments recorded in section C, in which the amount of strontium salt in 125$^{cm^3}$ of water is increased, a negative error is introduced,

which is not diminished by the presence of a large amount of ammonium oxalate, but when the dilution is increased to 250^{cm^3}, as is the case in the experiments given in section D, so that the conditions correspond more nearly to those recorded in sections A and B, the errors fall to a minimum. In the experiments recorded in section E, in which the dilution is increased to 500^{cm^3}, an error is introduced which is not prevented by the presence of a large excess of ammonium oxalate and which is independent of the amount of strontium salt used. Eight of the water filtrates and wash waters obtained in the experiments recorded in Table VI were tested for traces of strontium by the addition of alcohol, and in all cases a small amount of strontium was found, amounting in the average to 0·0010 grm. in 100^{cm^3} of water.

Barium Oxalate.

Barium oxalate according to Souchay and Lenssen* is soluble in 2,590 parts of cold water, and according to Bergman† is scarcely at all soluble in alcohol. The attempt was made to estimate barium by precipitation with ammonium oxalate in a mixture containing alcohol. It was found that in filtrates from oxalate precipitations in which 0·1–0·2 grm. of barium oxide, taken as the nitrate, had been precipitated in volumes of 100^{cm^3} containing 30^{cm^3} of absolute alcohol, and allowed to stand over night, treatment with sulphuric acid gave barium sulphate amounting in the average to no more than 0·0001 grm. of barium oxide. The insolubility of barium oxalate under these conditions, therefore, is practically complete.

The process for the estimation of barium was as follows: Ammonium oxalate was added to a solution of a barium salt, containing 30 per cent of its volume of alcohol, the mixture was allowed to stand over night, filtered on asbestos, the precipitate was washed by decantation with 100–200^{cm^3} of water containing 30 per cent of its volume of alcohol, and dried over a flame to insure the removal of alcohol. The crucible containing the precipitate was returned to the beaker also previously dried over a flame, 100–200^{cm^3} of water, 5–10^{cm^3} of strong hydrochloric acid, and 0·5–1·0 grm. of manganous chloride were added, and the solution was titrated at 35°–40° with permanganate. The results of the experiments, given in Table VII, A, show that barium, either as the nitrate or chloride, may be estimated in the manner described with a fair degree of accuracy.

* Ann. der Chem. (Liebig), xc, 102. † Bergman's Essays, i, 320.

TABLE VII.

BaO, taken as $Ba(NO_3)_2$. grm.	Ammonium oxalate. grm.	Volume at precipitation. cm^3.	Acid present during titration.	BaO found. grm.	Error. grm.
		A			
0·1165	0·2	100	HCl	0·1177	+0·0012
"	"	"	"	0·1170	+0·0005
"	"	"	"	0·1164	−0·0001
"	"	"	"	0·1151	−0·0014
"	"	"	"	0·1165	0·0000
"	"	"	"	0·1176	+0·0011
"	"	"	"	0·1164	−0·0001
0·2330	0·4	"	"	0·2319	−0·0011
"	"	"	"	0·2335	+0·0005
"	"	"	"	0·2342	+0·0012
BaO, taken as $BaCl_2$.					
0·0942	"	"	"	0·0952	+0·0010
"	"	"	"	0·0939	−0·0003
"	"	"	"	0·0941	−0·0001
0·1884	0·4	"	"	0·1893	+0·0009
"	"	"	"	0·1892	+0·0008
		B			
0·0942	0·2	200	H_2SO_4	0·0858	−0·0086
0·1884	0·4	"	"	0·1732	−0·0152
0·0942	0·2	500	"	0·0857	−0·0085

In the experiments given in section B of Table VII, the precipitate of barium oxalate was treated with sulphuric acid after the addition of the stated amount of water. The results show a large loss of oxalic acid probably due to the occlusion of some of the oxalic acid by the barium sulphate. This fact must prevent the use of sulphuric acid in an analytical process which depends upon the liberation of oxalic acid from barium oxalate.

Gravimetric Estimation of the Oxalates of Strontium and Barium.

It is well known that calcium may be weighed as the carbonate after a careful ignition of the oxalate, and it would seem probable that strontium might also be weighed as the carbonate. Precipitates of strontium oxalate, on asbestos, were ignited in a capped crucible from 2–8 minutes in the flame of a Bunsen burner and weighed as the carbonate, and in a single case the carbonate thus produced was converted by treatment with sulphuric acid to the sulphate and weighed as such. The results are given in Table VIII, and, while they show slight losses, the results are fairly accurate.

TABLE VIII.

	SrO, taken as $Sr(NO_3)_2$. grm.	SrO, calculated from $SrCO_3$ found. grm.	SrO, calculated $SrSO_4$ found. grm.
1	0·1120	0·1113	----
2	0·1120	0·1116	----
3	0·2435	0·2425	0·2437

Precipitates of barium oxalate were also ignited from 5–10 minutes and weighed as the carbonate. The results are given in Table IX, and are fairly accurate.

TABLE IX.

BaO, taken as $Ba(NO_3)_2$. grm.	BaO, found as $BaCO_3$. grm.	Difference. grm.
0·2912	0·2909	−0·0003
"	0·2901	−0·0011
"	0·2901	−0·0011

The results of this work may be summarized as follows: In the estimation of calcium by titration of the oxalate with permanganate, accurate results may be obtained when hydrochloric acid (with a manganous salt) is used as the solvent. Strontium salts may be precipitated by ammonium oxalate with practical completeness in a solution containing one-fifth its volume of 85 per cent alcohol, and with approximate completeness from water solutions at a dilution not exceeding 250$^{cm^3}$. Furthermore, strontium oxalate may be titrated by permanganate with accuracy when either sulphuric acid or hydrochloric acid (with a manganous salt) is used to liberate the oxalic acid. Barium salts may be precipitated with practical completeness by ammonium oxalate in a solution containing one-third its volume of alcohol (85 per cent) and the barium oxalate thus obtained may be dissolved in hydrochloric acid and titrated by permanganate after the addition of a manganous salt. Strontium and barium oxalates may be converted to the carbonates by ignition and weighed as such.

Art. XXVI.—*On Calaverite;* by S. L. Penfield and W. E. Ford.

Introduction.—In 1868 the late Professor F. A. Genth* assigned the name *Calaverite* to a massive telluride of gold, from the Stanislaus Mine, Calaveras County, California. It was shown by his analyses that it contained but little silver (3·0 to 3·5 per cent), thus differing from sylvanite from Transylvania which contains from 11 to 13 per cent. It corresponds, however, like sylvanite, to the general formula $[Au,Ag]Te_2$. He described it as having a bronze-yellow color and an uneven to subconchoidal fracture. As far as the difference in chemical composition between sylvanite and calaverite are concerned, it might be questioned whether the latter has a right to be regarded as a distinct species, for in their combinations with tellurium, gold and silver are isomorphous. Calaverite, however, has been supposed to have a crystalline structure different from that of sylvanite, for it has no distinct cleavage, and this property is one of the best means of distinguishing the mineral from sylvanite, which has a perfect cleavage in one direction, parallel to the clino-pinacoid. Krennerite, also, the orthorhombic species of the same general formula, $[Au,Ag]Te_2$, has a perfect cleavage, parallel to the base.

Calaverite was later described by Genth† from Boulder, Colorado, two analyses being given, one showing 2·24 and the other 3·03 per cent of silver. In 1895 W. F. Hillebrand‡ described calaverite from Cripple Creek, Colorado, giving three analyses of materials from different mines, containing respectively 3·23, 1·77 and 0·90 per cent of silver. The material for the first analysis given by him was from the Prince Albert Mine. It was well crystallized, and was sent to one of the writers of this paper (Penfield) for examination. The crystals, however, proved to be unusually perplexing, and although considerable time was spent in studying them the investigation did not lead to decisive results. In a brief note accompanying Dr. Hillebrand's article, it was stated that the crystals had certain angles which were nearly like those of sylvanite, and that with the material then at hand it did not seem possible to establish the system of crystallization with certainty. It was suggested, because of the lack of symmetry in the distribution of the faces, that the crystals probably belonged to the triclinic system.

* This Journal (2), xlv, p. 314.
† Am. Phil. Soc., xiv, p. 229, 1874 and xvii, p. 117, 1877.
‡ This Journal (3), l, p. 128.

Since the publication of Dr. Hillebrand's paper it has always been the intention to again take up the study of the crystallization of calaverite, and requests have been made to numerous friends to secure, if possible, material suitable for study. These requests have been generously responded to, and we take special pleasure in here expressing our obligations to Messrs. Lazard Cahn of New York, T. A. Rickard of Denver, and Maynard Bixby of Salt Lake City, for the pains which they have taken to secure the materials needed for the present investigation. In addition to the materials sent us by the gentlemen whose names have just been given, we have also the crystals furnished by Dr. Hillebrand, already referred to. Altogether we have been able to include in our investigation crystals from five different mines in the Cripple Creek region.

The results of the present investigation indicate that calaverite crystallizes in the *Monoclinic System*. The crystals are prismatic or lath-shaped, with their longer axes corresponding to the ortho- or symmetry-axis *b*. The development of the crystals thus corresponds to that commonly observed on epidote. Invariably, as observed by us, the crystals are striated parallel to their longer direction, due to oscillatory combinations of the forms in the ortho-dome zone. The oscillations generally give rise to a rounding of the edges in the striated zone, and often very irregular cross-sections result therefrom, as will be shown. When this prominent zone is studied with the reflection goniometer, there often results an almost unbroken succession of reflections of the signal as a crystal is turned. There is no especially prominent face in the zone which may be easily identified, and relied upon as a starting point in making a series of measurements. Terminal faces, on the other hand, are generally free from striations and are in every way satisfactory for measurement with the reflection goniometer. Uncertain or multiple reflections of the signal, due to vicinal development of the faces or other disturbing causes, were seldom encountered. All of the work of determining the system of crystallization, the axial ratio and the symbols of the forms had to be based upon measurements made from the terminal faces, and these being at times unequally developed, and always quite small, the problem proved to be an unusually difficult one. It may not be out of place to state at this point that in the unequal development of the crystal faces, in the scarcity of zones, and in the complex symbols derived from the measurements, calaverite crystals are unlike any that have ever come to the attention of the present writers. The crystals seem almost to present a contradiction to some of the laws of crystallography.

Determination of the Axial Ratio.—The crystal which

seemed to promise the best results, and which was selected first of all for study, is represented in orthographic projection upon the clino-pinacoid by figure 2, page 229. It was apparent on inspection that certain faces, *m*, *s*, *q*, *o*, and *p*, occurred in pairs, as demanded by monoclinic symmetry, and the monoclinic character was fully substantiated by measurements. Two of the forms, *m* and *p*, to which the symbols (110) and (111) are assigned, agree very closely with corresponding forms on sylvanite, as shown by the following comparison:

		Calaverite.	Sylvanite.
$m \wedge m'$,	$110 \wedge \bar{1}10 =$	63° 1′*	62° 56′
$p \wedge p$	$111 \wedge \bar{1}1\bar{1} =$	93 49	94 30
$m \wedge p$	$110 \wedge 111 =$	36 38*	37 3
$m' \wedge p$	$\bar{1}10 \wedge 111 =$	68 45*	

Taking the measurements marked by asterisks as fundamental, the following axial ratio has been calculated, with which, for comparison, that of sylvanite is also given:

Calaverite, $a : b : c = 1{\cdot}6313 : 1 : 1{\cdot}1449$; $\beta = 89° 47\frac{1}{2}'$
Sylvanite, " " $= 1{\cdot}6339 : 1 : 1{\cdot}1265$; $\beta = 89\ 35'$

As will be shown later, the forms *m* and *p* occur on most of the crystals, and, with the exception perhaps of the form lettered *o*, they are the most prominently developed of the terminal faces. We feel, therefore, that the choice of these as the unit prism *m* (110) and the unit pyramid *p* (111) is the best that can be made, especially as the axial ratio derived from them is so nearly like that of sylvanite. Taken in connection with the similarity in chemical composition between calaverite and sylvanite, it does not seem probable that such close agreement in crystalline characters is wholly a matter of accident.

Thus far the crystallization of calaverite seems simple and satisfactory; beyond this point, however, the results are almost startling from a crystallographic standpoint, since but few of the many faces observed have simple indices. As no possibility of simplifying the symbols has presented itself to us, it has been decided to give our results in such a form that they may be made use of by others, and we will ask our readers to reserve their judgment of our interpretation of the crystals until the results have all been presented.

Peculiarities of Crystallization: Method of measuring.—Although the crystals are highly modified, a scarcity of zonal relations among the terminal faces is noticeable. The only prominent zone is that of the forms lettered D, *p*, *o*, *q* and *s*, figure 2 et seq., also shown in the stereographic projection,

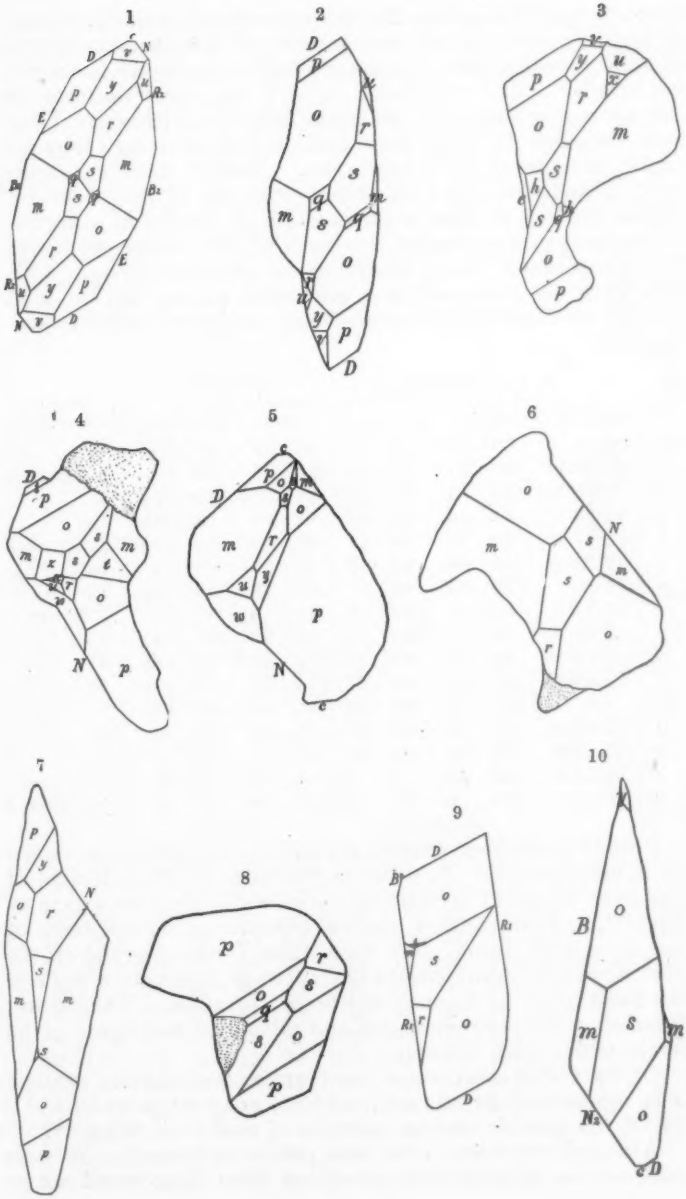
figure 30, page 242. Having in nearly every instance a distorted crystal to work with, showing few zonal relations and no clino-pinacoid, and not being able to make measurements from easily identified forms in the striated zone, it soon became evident that the identification of the small terminal faces with a one-circle goniometer would prove a most laborious undertaking. With a two-circle goniometer, on the other hand, both the measurement of the crystals and the interpretation of the results are very much simplified; in fact, without this instrument it would have been next to impossible to have identified the forms of some of the crystals. The crystals were orientated on the two-circle goniometer with the striated zone (the ortho-axis of the crystals) parallel with the axis of the vertical circle. Having adjusted so that a measurement between two *m* faces was obtained by turning the horizontal circle, the position half way between the two *m*'s was taken as the theoretical clino-pinacoid (010), or polar face, while the reading of the vertical circle at this point gave the position of a theoretical ortho-pinacoid (100) in the striated zone. The two readings served as starting points for making all measurements. The clino-pinacoid was observed on but few crystals and the ortho-pinacoid on only one, therefore nearly all of the measurements which will be recorded were made, not from actual faces, but from the theoretical positions of the (100) and (010) forms.

One peculiarity to be borne in mind in studying crystals of the monoclinic system is that the distribution of the faces at opposite extremities of the ortho-axis have a right- and a left-handed relation, as will be indicated by the figures. The two ends cannot be interchanged.

As has been stated already, the faces in the zone parallel to the ortho-axis are striated, and they oscillate with one another to such an extent that most of the crystals have very irregular cross-sections when viewed in the direction of their longer- or ortho-axis. In representing the crystals, orthographic projections upon the clino-pinacoid have been employed, and the figures are intended to show irregularities of contour, as well as variations in the relative size and distribution of the terminal faces as exhibited by the specimens.

In order to shorten and simplify the description of the crystals they will be treated in groups, as far as possible, and the symbols of the forms together with their measured and calculated angles will be condensed in tables. It would consume altogether too much space and be of too little interest to give separate tables of measured and calculated angles for each crystal which has been examined.

Occurrence No. 1. Crystals from the Monument Mine.—The material was presented to us by Mr. Cahn, and consists of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fifteen terminated crystals besides numerous fragments. Some of the fragments, which are portions of lath-shaped crystals without terminal faces, measure over a centimeter in length and breadth. The terminated crystals are quite uniform in size, averaging about 5^{mm} in length by 3^{mm} in thickness. They were detached from the matrix and looked as though they all might have come from one cavity. Nine of them are right-hand terminations, and are represented by figures 2 to 10. Figure 1 gives an ideal representation of the forms observed on the most symmetrically developed crystal, shown by figure 2. The terminal faces occurring on the nine crystals, with their symbols, measured and calculated angles, and the total number of times they were observed, are given in the following table:

		Measured.		Calculated.		Times observed.
	Symbols.	Vertical.	Horizontal.	Vertical.	Horizontal.	
m	110	00° 00′	31° 29′	00° 00′	31° 30½′	14
e	42·44·11	20 21	32 10	20 26	32 1	1, figure 3
t	13·20·4	24 5	23 10	23 38½	23 32½	3
q	11·29·5	33 4	15 46	32 52	15 30½	4
h	21·37·11	36 40	23 19	36 40	23 30½	2, figure 3
o	13·22·10	46 59	28 2	47 30½	28 18	18
p	111	54 44	46 51	54 48	46 54½	12
i	10·7·11	57 13	58 8	57 18	58 29	1, figure 4
y	296	76 21	30 28	76 38	30 54	5
v	2·11·10	81 52	38 15	81 48	38 43½	2
r	$\bar{1}0\cdot44\cdot15$	114 53	18 27	114 54	18 10½	10
w	$\bar{1}11$	125 6	46 46	124 55	46 48½	3
u	$\bar{1}\bar{1}\cdot18\cdot10$	127 8	30 55	127 32	31 28	5
x	$\bar{1}\bar{1}\cdot20\cdot6$	141 59	22 50	142 4	23 5	2
s	$\bar{1}\bar{1}\cdot62\cdot6$	142 25	8 3	142 4	7 50	16
z	$\bar{1}5\cdot22\cdot1$	174 9	22 42	174 34	22 46	1, figure 4

Five of the crystals studied are left-hand terminations, shown by figures 12 to 16. In order to facilitate the identification of the faces figure 11 is introduced, which is a mirror image of figure 1, and represents a possible symmetrical development of the prominent forms. Of the sixteen forms observed on the nine right-hand terminations twelve were observed on the five left-hand ends, and one additional form *n*. The forms, together with their measured and calculated angles, are given in the table which follows.

Of the forms observed on the fourteen terminations studied, *o* is represented by 26 faces, *s* by 23, *m* by 20, *p* by 19 and *r* by 13, the possible number of faces of each kind being 28.

Although the faces in the zone parallel to the ortho-axis were generally so striated that reflections from them could not be

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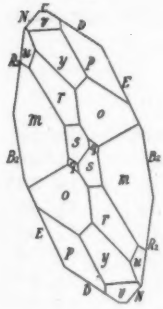

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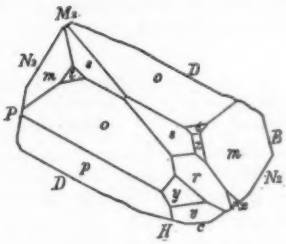

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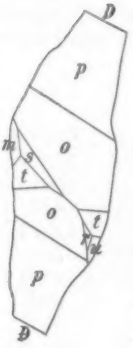

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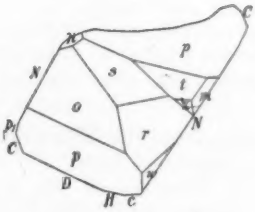

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	Symbols.	Measured. Vertical.		Measured. Horizontal.		Calculated. Vertical.		Calculated. Horizontal.		Times Observed.	
m	$1\bar{1}0$	00°	00′	31°	30½′	00°	00′	31°	30½′	6	
t	$13\cdot\bar{2}\bar{0}\cdot4$	23	33	23	12	23	38½	23	32½	5	
o	$13\cdot\bar{2}\bar{2}\cdot10$	47	13	28	14	47	30½	28	18	8	
n	$11\cdot\bar{1}\bar{4}\cdot10$	52	16	38	56	52	12	38	17½	1,	figure 15
p	$1\bar{1}1$	54	45	46	56	54	48	46	54½	7	
y	$2\bar{9}6$	76	40	30	18	76	38	30	54	1	
v	$2\cdot\bar{1}\bar{1}\cdot10$	81	48	38	27	81	48	38	43½	1	
r	$\bar{1}0\cdot\bar{4}\bar{4}\cdot15$	114	14	18	29	114	54	18	10½	3	
w	$\bar{1}\bar{1}1$	125	9	46	44	124	55	46	48½	1	
u	$\bar{1}\bar{1}\cdot\bar{1}\bar{8}\cdot10$	127	13	31	6	127	32	31	28	1	
x	$\bar{1}\bar{1}\cdot\bar{2}0\cdot6$	142	1	23	5	142	4	23	5	2	
s	$\bar{1}\bar{1}\cdot\bar{6}\bar{2}\cdot6$	142	3	8	10	142	4	7	50	7	
z	$\bar{1}5\cdot\bar{5}\bar{2}\cdot1$	174	28	22	38	174	34	22	46	2	

relied upon, the zone was carefully studied and a record kept of all especially prominent reflections. The results are summarized in the following table:

	Symbols.	Measured on vertical circle.	Number of observations.	Average.	Calculated.
B_2	75·0·11	11° 35′ to 11° 48′	3	11° 43′	11° 48′
C	501	15 36	1	15 36	15 53½
C_1	401	19 27 – 19 40	2	19 34	19 35
E	11·0·4	26 49 – 27 56	3	27 16	27 21
D	304	62 8 – 63 8	9	62 26	62 4
H	5·0·11	71 22 – 72 18	7	71 53	71 36
c	001	89 44 – 90 4	8	89 55	89 47½
L	$\bar{1}04$	99 50	1	99 50	99 45
M_1	$\bar{1}0{\cdot}0{\cdot}11$	122 24 – 122 49	4	122 38	122 23
M	$\bar{1}01$	124 27	1	124 27	124 55
M_2	$\bar{1}\bar{1}{\cdot}0{\cdot}10$	126 49 – 127 6	3	126 59	127 32
N_1	$\bar{1}\bar{1}{\cdot}0{\cdot}6$	141 41 – 142 40	4	142 13	142 4
N	$\bar{2}01$	143 22 – 144 21	7	143 56	144 28
N_2	$\bar{2}\bar{4}{\cdot}0{\cdot}11$	146 20 – 147 14	3	146 42	146 47
P_1	$\bar{2}\bar{5}{\cdot}0{\cdot}4$	167 8 – 167 16	3	167 11	167 9
R	$\bar{9}01$	170 14 – 170 44	2	170 29	171 0
R_1	$\bar{1}\bar{1}{\cdot}0{\cdot}1$	172 31 – 172 51	4	172 44	172 37
R_2	$\bar{1}\bar{5}{\cdot}0{\cdot}1$	174 10 – 175 45	4	174 55	174 35

Among the crystals from the Monument mine there was one twin which will be described later.

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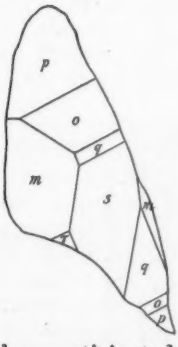


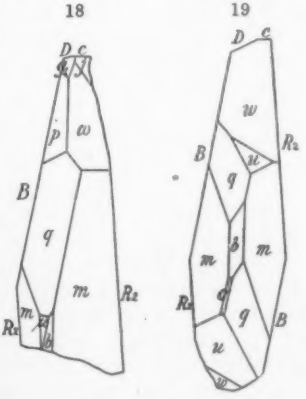
Occurrence No. 2.—Among the specimens sent by Mr. Bixby were some detached crystals somewhat resembling those just described, though certainly from a different mine. The suite consisted of a number of fragments and one terminated crystal, the latter measuring about 2^{mm} in greatest diameter and 4^{mm} in length. The crystal faces were not bright, and it was believed at first that it would be useless to attempt to measure the angles, but, realizing the importance of extending our investigation to material from as many sources as possible, the crystal was placed in the goniometer and gave far better reflections than anticipated. The reflections though not bright were perfectly distinct. The development of the forms is represented by figure 17. The terminal forms with one exception,

τ, are the same as those already recorded. In the striated zone a distinct reflection was obtained from a face corresponding to the ortho-pinacoid a(100), which has been observed only on this crystal.

The measured and calculated angles are as follows:

	Symbols.	Measured. Vertical.	Measured. Horizontal.	Calculated. Vertical.	Calculated. Horizontal.	Times observed.
m	110	00°00′	31°17′	00°00′	31°30½′	2
q	11·29·5	33 41	15 10	32 52	15 30½	1
o	13·22·10	46 50	27 45	47 30½	28 18	2
p	111	55 8	46 54	54 48	46 54½	2
s	$\bar{1}\bar{1}$·62·6	143 15	8 13	142 4	7 50	1
τ	$\bar{3}\bar{1}$·38·11	153 16	28 55	153 8	29 14	1
a	100	00 00	90 5	00 00	90 00	2
F	11·0·5	31 41	90 00	32 52	"	1
G	13·0·10	47 3	"	47 30½	"	1
N	$\bar{2}$01	144 22	"	144 28	"	2
R_1	$\bar{1}\bar{1}$·0·1	173 10	"	172 37	"	1

Although the discrepancy between the measured and calculated values is considerable in some cases, the agreement is sufficiently close to indicate that the forms are identical with those of the first occurrence. A similar irregularity of contour is also noticeable, as shown by the figure.



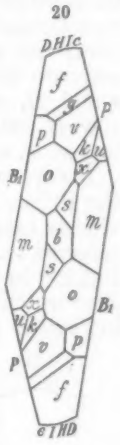
Occurrence No. 3. Crystals from the Moon Anchor Mine.—Our study is confined to two small crystals detached from a gangue specimen sent us by Mr. Rickard. The crystals are lath-shaped, measuring 1·5^{mm} in length and 2 by 0·3^{mm} in cross section. The development of the crystals is represented by figures 18 and 19. The gangue upon which the crystals occur seems to be a decomposed andesite, the calaverite having been deposited along with quartz and fluorite in a crevice. The forms together with their measured and calculated angles are recorded in the following table:

	Symbols.	Measured. Vertical.	Measured. Horizontal.	Calculated. Vertical.	Calculated. Horizontal.	Times observed.
b	010	00° 00′	00° 00′	00° 00	00° 00	2
m	110	00 00	31 28	00 00	31 30½	4
μ	17·40·2	9 58	14 22	9 30	14 48½	2
	33·80·4			9 47½	14 24	
q	11·29·5	32 25	15 33	32 52	15 30½	3
p	111	54 33	46 57	54 48	46 54½	1
g_1	10·15·22	72 6	52 49	71 36	52 38	1
w	$\bar{1}11$	125 16	46 47	124 55	46 48½	3
u	$\bar{1}\bar{1}$·18·10	127 40	31 6	127 32	31 28	2
j	$\bar{7}56$	128 50	53 30	129 11½	53 31	1
s	$\bar{1}\bar{1}$·62·6	144 13	7 55	142 4	7 50	1
σ	$\bar{2}$·10·1			144 28	8 33	
B_1	17·0·2	9 51	90 00	9 30	90 00	1
B	801			10 5½	"	
D	304	62 8	"	62 4	"	2
c	001	89 51	"	89 47½	"	2
R_1	$\bar{1}\bar{1}$·0·1	172 52	"	172 34	"	1
R_2	$\bar{1}\bar{5}$·0·1	175 1	"	174 35	"	1

On these two crystals, as indicated by the figures, attention may be called to the occurrence of the clino-pinacoid *b* (010), or polar face, and to the prominent developments of *m*, *w* and *q*. The forms g_1 and *j* have been observed by us on only the one crystal represented by figure 18. There is some uncertainty concerning *σ* (2·10·11), figure 19. It is a small face, apparently in the zone *m*, *q*, but it is very near to *s* ($\bar{1}\bar{1}$·62·6) of occurrence No. 1, which is in the zone *D*, *p*, *o* and *q*. The dome B is probably (801), which is in the same zone as *m* and *q*. In cross-section these crystals have a far more regular contour than those of the occurrences previously cited.

Occurrence No. 4.—The occurrence thus designated is that of a suite of specimens sent by Mr. Bixby with no special designation of the mine from which they came. The specimens resemble very closely those from the Moon Anchor mine. The crystals are lath-shaped, some of them very thin, attached to what appears to be an andesitic gangue. They have been deposited in crevices, and are associated with quartz and fluorite. Many of the crystals are much bent and cracked. Although there was an abundance of calaverite on the specimens only one crystal was found which seemed to offer any possibility of measurement. The end of the crystal when detached from the gauge measured about 1^{mm} in length and only 0·6 by 0·15^{mm} in cross-section. Although so very minute, the reflections from its faces were excellent: in fact this

crystal may be regarded as the best we have examined. Without a two-circle goniometer it would have been almost impossible to have measured more than a few of the angles of such a small crystal. With a two-circle goniometer, on the other hand, the measurements were made without difficulty. Altogether seventeen terminal faces were observed on this crystal, the area of whose cross-section is less than that of a hyphen on this printed page. The crystal, which is the most symmetrical in its development of any we have seen, is represented with ideal symmetry in figure 20. The clinopinacoid *b* (010) is present, and monoclinic symmetry is proved by the occurrence of the forms *m*, *o*, *p*, *f*, and *s* as pairs of faces, making in each case almost identical angles on either side of (010), as indicated by the horizontal circle measurements. A complete list of the angles measured on this crystal is given in the following table:



	Symbols.	Measured. Vertical.	Measured. Horizontal.	Calculated. Vertical.	Calculated. Horizontal.
b	010	00° 00′	00° 00′	00° 00′	00° 00′
m	110	"	31 32	"	31 30½
m	$\bar{1}10$	"	31 32	"	31 30½
o	13·22·10	47 10	28 12	47 30½	28 18
o	$\bar{1}3{\cdot}22{\cdot}\bar{1}0$	"	28 2	"	28 18
p	111	54 57	47 8	54 48	46 54½
p	$\bar{1}1\bar{1}$	"	46 41	"	46 54½
f	112	70 21	61 37	70 29	61 40
f	$\bar{1}12$	"	61 36	"	61 40
g	4·7·10	73 53	52 46	74 7	52 22
v	2·11·10	82 17	38 25	81 48	38 44
k	$\bar{1}0{\cdot}32{\cdot}21$	108 27	31 3	108 18	31 6
u	$\bar{1}1{\cdot}18{\cdot}10$	127 21	30 52	127 32	31 28
u	$11{\cdot}18{\cdot}\bar{1}0$	"	31 00	"	31 28
x	$\bar{1}1{\cdot}20{\cdot}6$	143 52	22 36	142 4	23 5
s	$\bar{1}1{\cdot}62{\cdot}6$	"	7 52	"	7 50
s	$11{\cdot}62{\cdot}\bar{6}$	"	8 00	"	7 50
B_1	17·0·2	9 26	90 00	9 30	90 00
B_1	$\bar{1}7{\cdot}0{\cdot}\bar{2}$	9 45	"	"	"
D	3 0 4	63 38	"	62 4	"
H	5·0·11	72 11	"	71 36	"
I	2·0·11	82 25	"	82 25	"
P	$\bar{1}1{\cdot}0{\cdot}2$	165 58	"	165 28	"
P	$11{\cdot}0{\cdot}\bar{2}$	165 26	"	"	"

Most of the terminal faces, *b*, *m*, *u*, *p*, *v*, *u*, *x* and *s*, are identical with those observed in previous occurrences. Of the new forms, *f*, *g* and *k*, the two former fall in a zone with D (304) and *v* (2·11·10), to which zone also *t* (13·20·4) belongs; compare the stereographic projection, page 242. The forms *s* and B_1 are somewhat doubtful. They may be σ ($\bar{2}$·10·1) and *B* (801); compare page 234. 11·62·$\bar{6}$, 110 and 17·02 are in a zone, as are also 2·10·$\bar{1}$, 110 and 801.

Occurrence No. 5.—This material includes the crystals from the Prince Albert mine sent to us by Dr. Hillebrand, and previously examined crystallographically by one of us, as already referred to. The crystals average from $\frac{1}{8}$ to 1^{mm} in diameter and 2^{mm} in length. Most of them are twinned according to laws which will be described later, but three which show no indication of twinning are represented by figures 21 to 23.

21 22 23

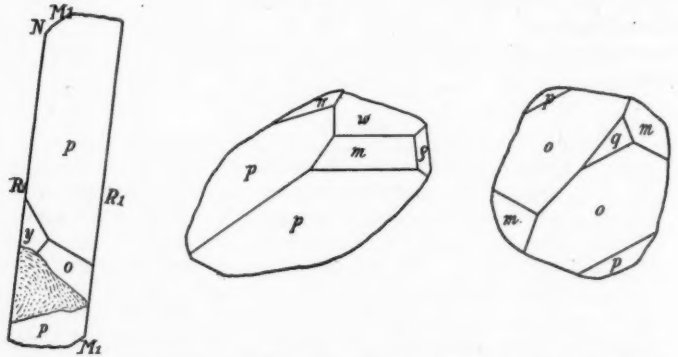
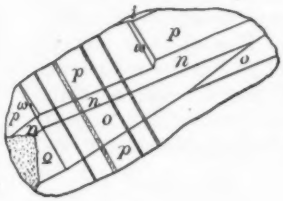


Figure 21 represents a left-hand termination, the others right-hand ends. One, figure 23, is a doubly terminated crystal, showing similar forms at both extremities of the axis of symmetry. The prominent forms are those observed on other occurrences. The new forms π and ρ are each represented by one small face. The symbols of the forms and the measured and calculated angles are as follows:

	Symbols.	Measured.				Calculated.				Times Observed.
		Vertical.		Horizontal.		Vertical.		Horizontal.		
m	110	00°	00′			00°	00′	31°	30½′	3
q	11·29·5	31	59	15°	58′	32	52	15	30½	1
o	13·22·10	47	3	28	1	47	30½	28	18	3
p	111	54	50	46	50	54	48	46	54½	6
π	22·18·27	59	56	56	10	60	5	56	31	1
y	296	76	35	30	35	76	38	30	54	1
ρ	$\bar{4}\bar{4}$·21·2	176	32	52	45	176	18	52	9	1

Twinning.—Two laws of twinning have been determined which may be stated as follows: 1. The twinning plane is in the ortho-dome zone, at 90° to 101. 2. The twinning plane is the ortho-dome 101. According to both laws the symmetry axis and the positions of the *p* faces are the same for both the normal and twin positions. Penetration twins have also been observed with the symmetry axes, or the striated zones, crossed

24



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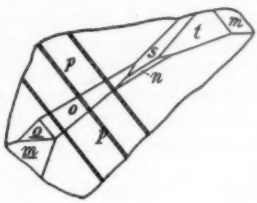

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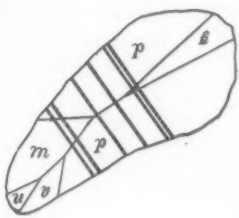
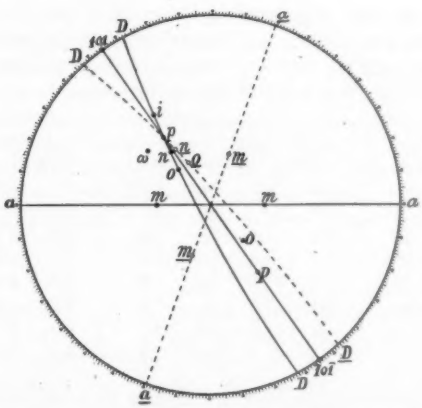


27



at angles of about 90°, but no crystals have been found from which sufficiently accurate measurements could be obtained for determining the exact law of twinning.

The first law of twinning has been observed only on crystals from the Prince Albert mine (Occurrence No. 5). The twinning is partly of the nature of two individuals meeting along the twinning plane and partly of the nature of twin lamellæ, revealed by a series of striations crossing the terminal faces at right angles to the intersection of two *p* faces. Figures 24 to 26 represent three individuals which illustrate this law of twinning, and although the figures do not show the twinning at all distinctly, it is doubtful whether any other kind of illustration

would answer the purpose better. The stereographic projection, figure 27, is better adapted for the purpose. The diameter of the circle, passing through 101, $\bar{1}0\bar{1}$ and the poles lettered *p*, represents the twinning plane, and symmetrically on either side of it are the poles of the two *n* and two *o* faces, making small angles with one another. The poles of the four *m* faces, two in normal and two in twin position, serve to make the orientation clear.

In figure 24 the faces in the upper right-hand portion are in normal position, except for the occasional crossing of twin lamellæ, as indicated by the striations. The faces *n* and *o* below and to the left are in twin position, and make reëntrant angles with the corresponding planes of the normal crystal. The two *p* faces are common to both individuals. The angles $n \wedge n$ and $o \wedge o$, measured over the twinning plane, are as follows:

	Measured.	Calculated.
$n \wedge n$	3° 21′	3° 14′
$o \wedge o$	7 2	6 54

The form *ω* was observed only on this crystal and appears as a very narrow, somewhat tapering face, intersecting *p* and disappearing against a twin lamella. The measured and calculated angles of this crystal are as follows:

		Measured				Calculated			
	Symbols.	Vertical.		Horizontal.		Vertical.		Horizontal.	
p	111	54°	48′	46°	50′	54°	48′	46°	54½′
p	$\bar{1}1\bar{1}$	"	"	46	50	"	"	46	54½
n	11·14·10	52	11	38	34	52	12	38	17½
n	of twin	57	10	38	34	57	24	38	17½
o	13·22·10	47	26	28	6	47	30½	28	18
o	of twin	62	0	28	2	62	5	28	18
ω	20·15·12	40	16	47	12	40	26	47	8
i	10·7·11	57	5	58	4	57	18	58	29

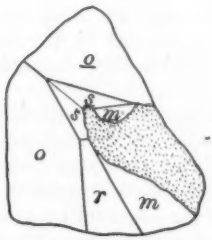
On the crystal represented by figure 25 only the small *o* and *m* faces to the left are in twin position, the *o* faces making a reëntrant angle at the twinning plane. A few of the angles of this crystal are as follows:

		Measured				Calculated.			
	Symbols.	Vertical.		Horizontal.		Vertical.		Horizontal.	
p	111	54°	50′	46°	47′	54°	48′	46°	54½′
p	$\bar{1}1\bar{1}$	"	"	46	47′	"	"	46	54½
o	13·22·10	47	6	28	5	47	30½	28	18
o	of twin	62	28	28	5	62	5	28	18
m	$\bar{1}10$	00	00	31	34	00	00	31	30½
m	of twin	109	45	31	35	109	35	31	30½

The crystal represented by figure 26 appears for the most part like a normal individual, crossed, however, by twin lamellae as indicated by the striations. The form lettered *s* seems to be in twin rather than in normal position.

The second law of twinning, where 101 is the twinning plane, has been observed on two crystals, one from the Monument the other from the Prince Albert Mine. These are illustrated by figures 28 and 29, respectively. In the crystal rep-

28



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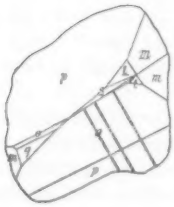


resented by figure 28 the faces *o*, *m* and part of *s* above are in twin position. The twinning plane separates the two *o* faces, runs through *s*, and disappears in that portion, stippled in the figure, where the crystallization has been interrupted. The *m* faces make a reëntrant angle. The *s* faces in normal and twin position fall almost together, making, according to calculation, an angle of only 0° 44′ with one another. In the crystal under consideration *s* was not a very good face. The measured angles are as follows:

	Symbols.	Measured.				Calculated.			
		Vertical.		Horizontal.		Vertical.		Horizontal.	
m	$1\bar{1}0$	00°	00′	30°	52′	00°	00′	31°	30½′
m	of twin	70	33	31	37	70	26	31	30½
o	$\bar{1}\bar{3}\cdot\bar{2}\bar{2}\cdot\bar{1}0$	47	3	28	13	47	30½	28	18
o	of twin	117	40	28	13	117	56	28	18
r	$\bar{1}0\cdot\bar{4}\bar{4}\cdot\bar{1}5$	113	59	18	34	114	54	18	10½
s	probably of twin	146	32	8	8	147	20	7	50

In the crystal from the Prince Albert Mine, figure 29, both laws of twinning are combined. The first law is indicated by twin lamellæ crossing the lower portion of the crystal. The faces in the lower left-hand portion of the figure may be regarded as belonging to a single individual in normal position. To the right the two *m* faces meet along the twinning plane, which seems to run for a ways through *s* and then disappears. The salient angle made by the two *m* faces, measured over the

twinning plane, is 35° 2′, calculated 35° 4′. The measured angles are as follows:

		Measured.		Calculated.	
	Symbols.	Vertical.	Horizontal.	Vertical.	Horizontal.
m	110	00° 00′	31° 39′	00 00	31° 30½′
m	of twin	109 41	31 40	109 38	31 30½
t	$\bar{1}\bar{3}\cdot 20\cdot\bar{4}$	24 14	23 19	23 38½	23 32½
t	of twin	86 1	23 31	85 57	23 32½
o	13·22·10	47 14	28 11	47 30½	28 18
p	111	54 49	46 49	54 48	46 54½
q	11·29·5	32 9	15 21	32 52	15 30½
s	of twin	147 4	7 52	147 20	7 50

As far as the angles of the crystals are concerned, the second law (twinning plane 101) might be considered as alone sufficient for explaining the two kinds of twinning. Instead of the first law, as stated above, it might then be said that the crystals were twinned about 101, but were united by a *composition face* at right angles to the twinning plane. Since we have in figure 29 a combination of the two kinds of twinning, it has seemed to us simplest to explain it as according to two laws.

Summary.—There have thus far been presented in the tables of angles sufficient data to indicate that there are certain planes which occur on calaverite crystals repeatedly, and with such constancy in their angles that they can not be regarded as in any way accidental. There are no forms more frequent in their occurrence and more prominent in their development than those designated as *m* (110) and *p* (111), unless it is, perhaps, *o* (13·22·10). If it be accepted that *m* (110) and *p* (111) have been well chosen as fundamental forms, then the crystallographic relations between calaverite and sylvanite may be expressed as follows:—Both are closely related not only in chemical composition, but also in their axial ratios and in their axial inclinations β.—Both are alike in crystallizing in the monoclinic system, and in having the dome (101) as twinning plane.—Calaverite differs from sylvanite in having no distinct clino-pinacoid cleavage, and in having, with few exceptions, different forms, most of which must be designated by unusually complex indices.

The symbols assigned by us to the calaverite forms are those which seem to correspond most nearly with the results of our measurements. No one can appreciate more fully than the writers that many of the symbols are so complicated that it is almost impossible to believe that they are true. On the other hand, we fail to find any way of simplifying them which does

not cause discrepancies in the angles greater than the character of the reflections would seem to warrant. It is probable that some of the symbols will need revision and change. The crystals which we have been able to examine are such as might be designated as *good*, though they are not of the very best quality. It should be explained also that all of the crystals in our possession have been studied and all of the results given, not merely a selection of *best values*. If one could have a larger variety of occurrences to select from, it is likely that some exceptionally good crystals might be found from which more exact and reliable measurements could be obtained. A careful study of such crystals would be of great value, for the correctness of the complex symbols indicated by the measurements made by us needs verification. One especially noteworthy feature of the symbols as given by us is that eleven, or some multiple of it, appears in many of them; though the significance of this, if there is any, is not apparent.

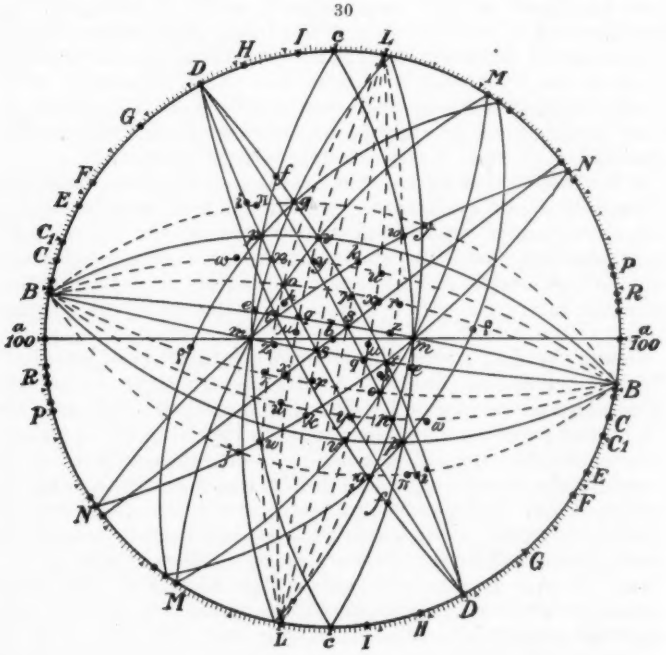
It is possible that by adopting another orientation some simplification of the symbols may result. The chances for bringing about much simplification, however, do not seem to be very promising, and any change in orientation must necessarily do away with the apparent similarity in crystallization between calaverite and sylvanite, as indicated by us on page 240.

It was noted in a recent number of Nature* that Mr. G. F. Herbert Smith had discussed crystals of calaverite before the Mineralogical Society of London, and described them as "triclinic, but pseudo-monoclinic owing to twinning about an axis parallel to the prismatic zone." Upon observing this, we immediately communicated with Mr. Smith, sending him the results of our investigation, and he in reply has kindly sent us a brief statement of his work. He expects soon to publish his results, and we do not feel at liberty to discuss them at this time. It may be stated, however, that he has in the three-circle goniometer recently described by him† an instrument, regarded as especially adapted to the study of such complex crystals as those of calaverite, by means of which he is able to discover zonal relations which ordinarily would escape detection. From the study of these he is led to assign simple indices to the majority of the forms, which necessitates, however, the assumption of triclinic symmetry and a peculiar twinning. As far as the angles and the distribution of the faces are concerned, his crystals, like ours, evidently satisfy the conditions of monoclinic symmetry. We quote the following

* Vol. lxlii, p. 555, 1901.
† Min. Mag., vol. xii, p. 175, 1899.

from his letter:—"Unless, however, the crystals are regarded as triclinic twins it is impossible to obtain simple indices. This, I allow, is the only argument in favor of this view; there are no reëntrant angles. I do not know whether I shall persuade any one to share this view. If the crystals are twinned there must be extraordinarily intimate penetration."

The problem may, perhaps, resolve itself as follows:—Either in the assumption of monoclinic symmetry (which the crystals apparently possess) with complex symbols, or triclinic sym-



metry (wholly obscured by twinning and resulting in pseudo-monoclinic symmetry) with simple indices.

When the present article was nearly completed we learned from Dr. Palache of Cambridge that he and Professor Moses of New York were also engaged upon the study of calaverite crystals. They both have found the same forms as observed by us, with few exceptions, and also have crystals which are far more complex. It may be expected that the results of their investigation will appear in due time.

It is not claimed that the results as set forth in the present communication furnish an explanation of the crystallization of calaverite. They are presented rather as an accumulation of data which has enabled us to figure and, to a certain extent at least, to describe the crystals, as also to point out close similarities in axial ratios and twinning between calaverite and sylvanite, which, if wholly accidental, are certainly remarkable coincidences. Although our results may not be conclusive nor wholly satisfactory, they are presented in such shape that others may make use of them in formulating any theories they may entertain concerning the crystallization of this remarkable mineral.

For convenient reference all of the forms which have been recorded in the foregoing pages are shown in stereographic projection, figure 30, and are given in the following tables, together with their calculated two-circle angles:

Terminal Forms.

	Symbols.	Vertical.	Horizontal.		Symbols.	Vertical.	Horizontal.
b,	010	00°00′	00°00′	g_1,	10·15·22	71°36′	52°38′
m,	110	00 00	31 30½	*g*,	4·7·10	74 7	52 22
μ,	17·40·2	9 30	14 28½	*y*,	296	76 38	30 54
	33·80·4	9 47½	14 24	*v*,	2·11·10	81 48	38 43½
e,	4 4 1?	19 35	33 5	*k*,	$\bar{1}0\cdot32\cdot21$	108 18	31 6
	42·44·11	20 26	32 1	*r*,	$\bar{1}0\cdot44\cdot15$	114 54	18 10½
t,	13·20·4	23 38½	23 32½	*w*,	$\bar{1}11$	124 55	46 48½
g,	11·29·5	32 52	15 30½	*u*,	$\bar{1}\bar{1}\cdot18\cdot10$	127 32	31 28
h,	21·37·11	36 40	23 30½	*j*,	$\bar{7}56$	129 11½	53 31
ω,	20·15·12	40 26	47 8	*x*,	$\bar{1}\bar{1}\cdot20\cdot6$	142 4	23 5
o,	13·22·10	47 30½	28 18	*s*,	$\bar{1}\bar{1}\cdot62\cdot6$	142 4	7 50
n,	11·14·10	52 12	38 17½	s_1,	$\bar{2}\cdot11\cdot1$?	144 28	7 47
p,	111	54 48	46 54½	*σ*,	$\bar{2}\cdot10\cdot1$?	144 28	8 33
i,	10·7·11	57 18	58 29	*τ*,	$\bar{3}\bar{1}\cdot38\cdot11$	153 8	29 14
π,	22·18·27	60 5	56 31	*z*,	$\bar{1}\bar{5}\cdot22\cdot1$	174 34	22 46
f,	112	70 29	61 40	*ρ*,	$\bar{4}\bar{4}\cdot21\cdot2$	176 18	52 9

Forms in the Zone 100–001.

Symbols.	Vertical.	Symbols.	Vertical.	Symbols.	Vertical.
a, 100	00° 00′	G, 13·0·10	47 30½	N_1, $\bar{1}\bar{1}\cdot0\cdot6$	142° 4′
B_2, 9 0 1	8 59½	D, 304	62° 4′	N, $\bar{2}$ 0 1	144 28
B_1, 17·0·2	9 30	H, 5·0·11	71 36	N_2, $\bar{2}\bar{4}\cdot0\cdot11$	146 47
B, 801	10 5½	I, 2·0·11	82 25	P, $\bar{1}\bar{1}\cdot0\cdot2$	165 28
B_3, 75·0·11	11 48	*c*, 0 0 1	89 47½	P_1, $\bar{2}\bar{5}\cdot0\cdot4$	167 9
C, 501	15 53½	L, $\bar{1}$ 0 4	99 45	R_2, $\bar{9}01$	171 0
C_1, 401	19 35	M_1, $\bar{9}\cdot0\cdot10$	122 8	R_1, $\bar{1}\bar{1}\cdot0\cdot1$	172 34
E, 11·0·4	27 21	M, $\bar{1}$01	124 55	R_2, $\bar{1}\bar{5}\cdot0\cdot1$	174 35
F, 11·0·5	32 52	M_2, $\bar{1}\bar{1}\cdot0\cdot10$	127 32		

Considerable time has been devoted to the study of the zonal relations of calaverite, with the results shown in the stereographic projection, figure 30, which may be summarized as follows:

1. *D* (304), *i* (10·7·11), *p* (111), *n* (11·14·10), *o* (13·22·10), *q* (11·29·5) and *s* (11·62·6̄). Symbol of the zone (4̄ 1 3). This is the principal zone, and almost the only one which is apparent on simple inspection of the crystals. A possible simpler symbol for *s* is (2·11·1̄), also in this zone, but most of the measurements indicate the more complex symbol.
2. *D* (304), *f* (112), *g* (4·7·10), *v* (2·11·10) and *t* (1̄3̄·20·4̄). Symbol of the zone (4 2 3̄).
3. *c* (001), *f* (112), *p* (111), *m* (110) and *w* (11 1̄). Symbol of the zone (1̄ 1 0).
4. *m* (110), *k* (1̄0·32·21), *w* (1̄11), *j* (7̄56), and N (3̄01). Symbol of the zone (1 1̄ 2).
5. *M* (1̄01), *g* (4·7·10), *p* (111) and *ρ* (44·21·2̄). Symbol of the zone (1 2̄ 1).
6. *m* (110), *n* (11·14·10) and *g* (4·7·10). Symbol of the zone (10·1̄0·3).
7. *m* (110), *o* (13·22·10), *v* (2·11·10) and M_1 (9̄·0·10). Symbol of the zone (10·1̄0·9).
8. *B* (801), *q* (11·29·5), *σ* (2·10·1̄)? and *m* (1̄10). Symbol of the zone (11 8̄).
9. B_1 (17·0·2), *s* (11·62·6̄) and *m* (1̄10). Symbol of the zone (2·2·17̄).
10. B_2 (901), *p* (111) and *v* (2·11·10). Symbol of the zone (18 9̄).
11. *b* (010), *s* (1̄1·62·6), *x* (1̄1·20·6) and N_1 (1̄1·0·6). This is the only case where two pyramidal forms have been observed in a zone between *b* and a form in the striated zone. Furthermore it is exceptional to find forms in the striated zone having the same vertical circle angles as the pyramids.

In addition to the foregoing there are a number of very close approximations to zones, some of which are indicated by dashed great circles in figure 30. These are drawn from (901) and (1̄·0·4), and although probable zonal relations seem to be indicated by the projection, the symbols assigned to the forms do not quite satisfy the zonal equations, and possible changes, indicating greater simplicity of the symbols, do not suggest themselves.

Chemical relations of Sylvanite and Calaverite.—Both minerals conform to the general formula $[Au,Ag]Te_2$, silver being regarded as isomorphous with gold. In sylvanite the proportion of gold to silver is near 1:1, so that the formula may be written $AuAgTe_4$. The percentage of silver

demanded by the formula is 13·4, whereas the published analyses show from 11·50 to 13·86 per cent. An analysis of sylvanite from Cripple Creek by Palache* yielded 12·49 per cent of silver and a ratio of Au : Ag=1 : 0·87. As most analyses of sylvanite indicate less than 12 per cent of silver, their agreement with the formula $AuAgTe_4$ is only approximate. Calaverite, on the other hand, is a nearly pure gold telluride, conforming closely to the formula $AuTe_2$, though always containing some silver, and at times, as indicated by the analyses, as high as 3·5 per cent. Although chemically there is not a very great difference between calaverite containing 3·5 per cent of silver and sylvanite containing 11·5 per cent, still there is evidently a tendency for sylvanite to conform closely to the formula $AuAgTe_4$ and calaverite to the formula $AuTe_2$. Thus from a chemical standpoint alone calaverite may well be regarded as a distinct mineral species. The relation between the two minerals is analogous to that existing between calcite and dolomite, and as the latter are closely related crystallographically, so calaverite and sylvanite are closely related as indicated by their similarity in axial ratios and twinning.

In order to distinguish between sylvanite and calaverite, the following method of testing, which has been applied to all of the occurrences examined by us, may be recommended: The powdered mineral when boiled in a test-tube with concentrated nitric acid is quickly oxidized, the silver and tellurium going into solution, gold being left. The clear solution, decanted into another test tube, diluted, and tested with hydrochloric acid, gives a precipitate of silver chloride, which is considerable if the mineral is sylvanite, but is slight, or amounts perhaps only to a turbidity, if the mineral is calaverite. After washing the gold by decantation it may be dissolved in a few drops of aqua-regia, indicating a complete separation of gold and silver.

Specific gravity determinations and quantitative estimations of gold and silver have been made on specimens from the Monument Mine and from the unknown Cripple Creek Mine designated as Occurrence No. 2. Of material from the first source a single fragment weighing 0·7729 grams was employed, while from the second source a number of fragments weighing 1·2532 grams were available. The specific gravity determinations were taken with much care on a chemical balance. The results by Penfield are as follows:

* This Journal (4), x, p. 422, 1900.

	Monument Mine.			Occurrence No. 2.			Theory.
Sp. Gr...	9·328	Ratio		9·388	Ratio		$AuTe_2$
Au	40·99	·209	·225	42·77	·217	·221	44·03
Ag	1·74	·016		0·40	·004		----
Te	[57·25]	·458		[56·75]	·455		55·97
Gangue.	0·02			0·08			100·00
	100·00			100·00			

The ratio of Au+Ag: Te in both analyses is 0·98 : 2·00, or very nearly 1 : 2. The second occurrence approaches very near to a simple gold telluride, the per cent of silver, 0·40, being the smallest thus far recorded in any published analysis of calaverite. The specific gravity determinations are a few tenths higher than generally given; from the nature of the material, however, and the care exercised in taking them they must be very exact. Of the other occurrences examined crystallographically by us, No. 5, from the Prince Albert Mine, contains 3·23 per cent of silver, as determined by Hillebrand, and the others, occurrences 3 and 4, are probably about like the material from the Monument Mine, judging from qualitative tests.

In all of his publications on calaverite Genth describes the mineral as having a bronze-yellow color. This seems to us misleading, for, although the crystals have at times a yellowish cast, the brightest and best of them are silver-white. Some of the dull crystals examined by us have a gray color, very like that of tarnished silver.

It is interesting to note the production of gold from the Cripple Creek region, as communicated to us by Mr. T. A. Rickard of Denver. During 1900 the production amounted to 877,972 ounces, valued at $18,147,681, and it is probable that the most of this vast amount was derived from calaverite. It was practically all derived from telluride ores, as very little free gold is found in the district, and that only in the uppermost portions of the veins, near the surface.

Sheffield Laboratory of Mineralogy and Petrography,
Yale University, New Haven, July, 1901.

SCIENTIFIC INTELLIGENCE.

1. *On Temporary Set;* by C. BARUS.—Following the suggestions of my last paper* I have since been able to map out the occurrence of what I shall call temporary set, distinguished from permanent set inasmuch as the former may be shaken out of a metal by molecular agitation (without heat, as for instance by magnetization of iron). The latter cannot, of course, be shaken out of the metal. Temporary set ($d\theta$) is instantaneously imparted; it begins with the zero of twist (θ), increasing at an initial rate $d\theta/\theta = \cdot 004$, the rate gradually diminishing to zero when the (elastic) obliquity of the external fibre of the twisted wire exceeds ·002 radians, after this temporary set becomes unstable, passing into permanent set. The maximum amount of temporary set may be estimated as ·0015 of the maximum twist within the elastic limits. Its variation depends not on the impressed strain but on the *antecedent* strain, i. e., the strain between two successive molecular agitations and which may lie on both sides of zero.

2. *Some new rock-types.*—KENYTE. This name has been applied by J. W. Gregory to "liparitic representatives of an olivine-bearing nepheline syenite, consisting of anorthoclase phenocrysts with or without some augite and olivine phenocrysts and a glassy or hyalopilitic groundmass which varies in color from grayish green to a deep sepia-brown. Aegyrine, if present, occurs in small granules; ænigmatite and quartz are absent." The rocks occur as surface lava flows on Mount Kenya in East Africa. They are supposed to be closely related to pantellarites but no analyses are given of them, and as the glassy base is stated to gelatinize with acid and to contain abundant soda, it is difficult to see why they are not glassy phonolites especially as they are held to be surface representatives of the nephelite syenite of the central core.—*Q. J. Geol. Soc.*, lvi, p. 211, 1900.

KEDABEKITE. E. von Federov has given this name to a rock occurring in dike form in the vicinity of the Kedabek mines in the Government Elisabethpol, Transcaucasia. It is very fine granular, of a dark gray with a tone of green. It consists of basic plagioclase, a lime-iron garnet ("aplome") and a strongly pleochroic pyroxene called *violaite* (conf. p. 86 of this volume). The type is held to be remarkable in that it unites such different kinds as augite-garnet rock and diabase. The occurrence is in close relation with an augite-garnet rock and is held to be a local facies of a neighboring diabase. The analysis by A. Kupffer gave:

	SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	CaO	MgO	Na_2O	K_2O	Ign.	
1	44·64	18·54	6·63	4·65	·09	22·17	2·52	·80	·05	·18	=100·27
2	44·11	19·38	5·17	5·44	—	21·98	2·90	·50	·13	·26	= 99·87

The type is mentioned as also occurring in the mining district of Bogoslowsk.—*Separate;* conf. also *Annuaire geol. et min. de la Russie*, iv, Liv. vi, p. 137. L. V. P.

* This Journal, xi, 1901, p. 97.

Obituary.

Joseph LeConte, Professor of Geology and Natural History in the University of California, died on the sixth day of July in the 88th year of his age. His death occurred in the Yosemite Valley, California.

Professor LeConte was a noble example of the type of man, now rare, whose distinction and influence are due to breadth of knowledge in all fields of science and clearness of perception and exposition rather than to that exclusive mastery of the minute details of some one branch of science so essential to the expert specialist.

His originality of thought and powers of research are well expressed in the series of papers finally published in 1880 under the title "Light, an exposition of monocular and binocular vision." In this work the dominant characteristics of his mind are exhibited in the combination of a deep and thorough comprehension of the laws of the visible and measurable phenomena of optics, with a keen appreciation of the subtle and invisible workings of the sensitive eye and perceiving mind by which physical vibrations of light are transmuted into conscious sight. Psychology, in his thought, was intimately associated with physiology and physics.

His "Elements of Geology" (1st edition, 1878) has been used by a generation of students and is distinguished for the clearness of its exposition of the principal facts and laws of the science of geology. The philosophical problem connected with the adaptation of evolution to social life, education and religion deeply interested him: and his books "Religion and Science" (1873) and "Evolution and its relations to religious thought" (1887) opened the truths of modern science to many minds that would have long remained in ignorance except for the keen human sympathy and teaching capacity which were prominent traits of his character. He was a man of charming personality, beloved as well as admired by all who met him.

Of Huguenot ancestry, he was born in Georgia, Feb. 26, 1823. He was educated as a physician, though the greater part of his life was spent as a teacher. He studied with Agassiz at Harvard, taking the degree of B.S. in geology and zoology in 1851. He held several professorships in Georgia and South Carolina colleges before the year 1869, when he was appointed Professor of Geology and Natural History in the new University of California, the position he occupied to the end of his life.

He published numerous papers and books on scientific, philosophical and educational subjects. The degree of LL.D. was conferred by the University of Georgia in 1879. He was a member of the National Academy of Sciences, the American Philosophical Society, the American Academy, the New York Academy, the Geological Society of America, the American Association and other scientific societies. He was acting president of the International Congress of Geologists at its meeting in Washington in 1891. W.

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J. WILEY & SONS, New York.—**System of Mineralogy** of J. D. DANA. 6th edit. by EDWARD S. DANA. lxiii, 1134 pp. large 8vo., 1892. $12.50. Appendix I, 75 pp., June 1899. $1.00. 5th edit., 1868, with three appendices, 1872, 1875, 1882. $5.00.—**Manual of Mineralogy & Lithology,** by J. D. DANA. 4th edition. 517 pp. 12mo., 1887, $2.00.—**Text-book of Mineralogy,** by E. S. DANA. Revised edition. 593 pp. 8vo., 1898, $4.00.—**Minerals and How to study them;** a book for beginners in Mineralogy, by E. S. DANA. 380 pp. 12mo., 1895, $1.50.—**Text-book of Elementary Mechanics,** by E. S. DANA. 300 pp. with numerous cuts, 12mo., 1881.

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